Elementary, Economic Experiments in Physics by Reginald F. Melton

IV. apparatus guide

Apparatus Guide

to

ELEMENTARY, ECONOMIC EXPERIMENTS IN PHYSICS

by

REGINALD F. MELTON

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FOREWORD

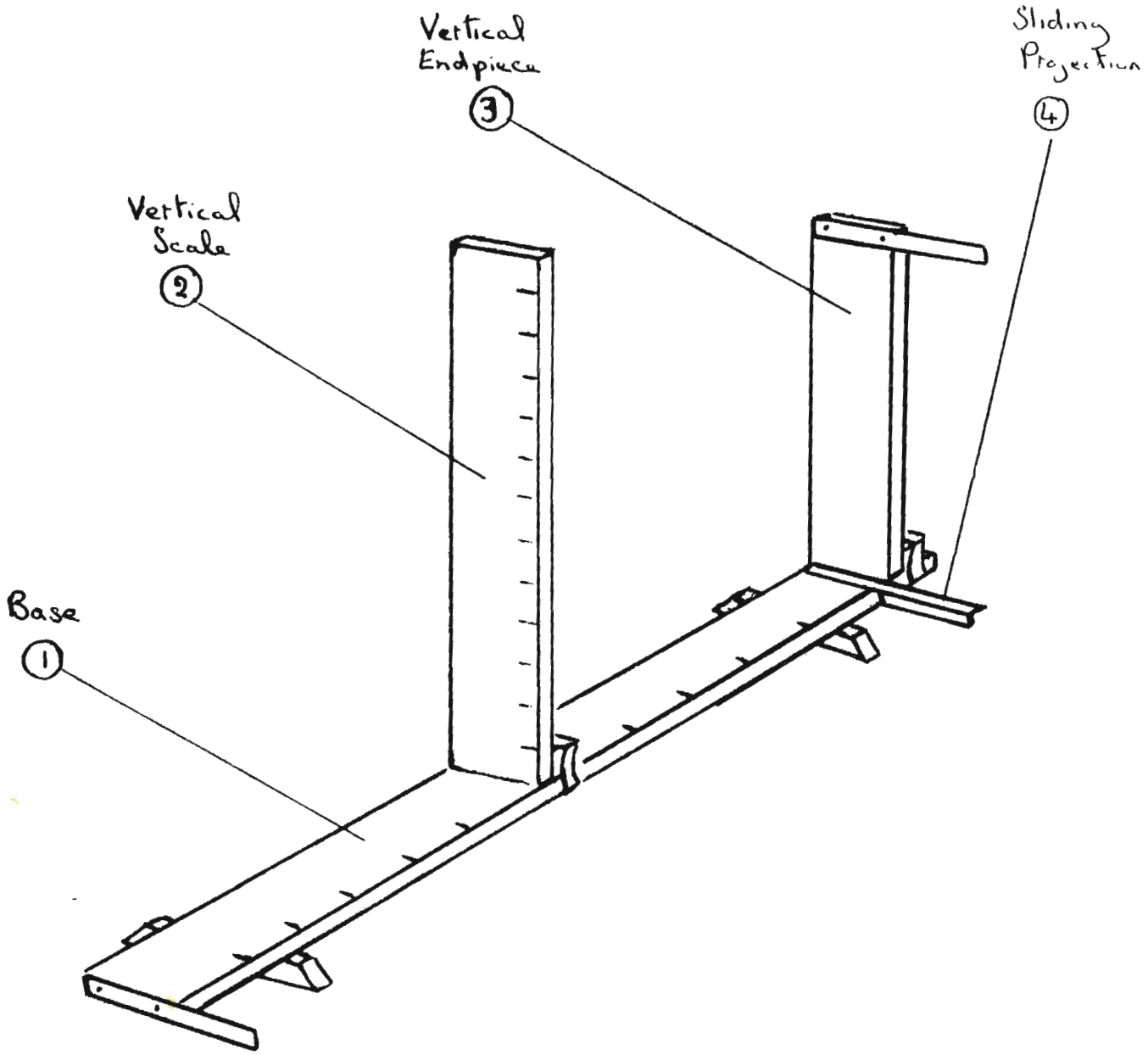
'Triple E Physics' is basically a package consisting of four guides: Student Guide, Teacher's Guide, Apparatus Guide and Administrator's Guide.

The Apparatus Guide is fundamental to the whole program. The apparatus it describes has been developed specifically for Developing Countries in the realization that their economies are very limited, and that by necessity their schools have not only limited laboratory facilities, but also stringent financial resources. Apparatus has therefore been designed for economy, for ease of operation under limited laboratory conditions, and for ease of production under local conditions.

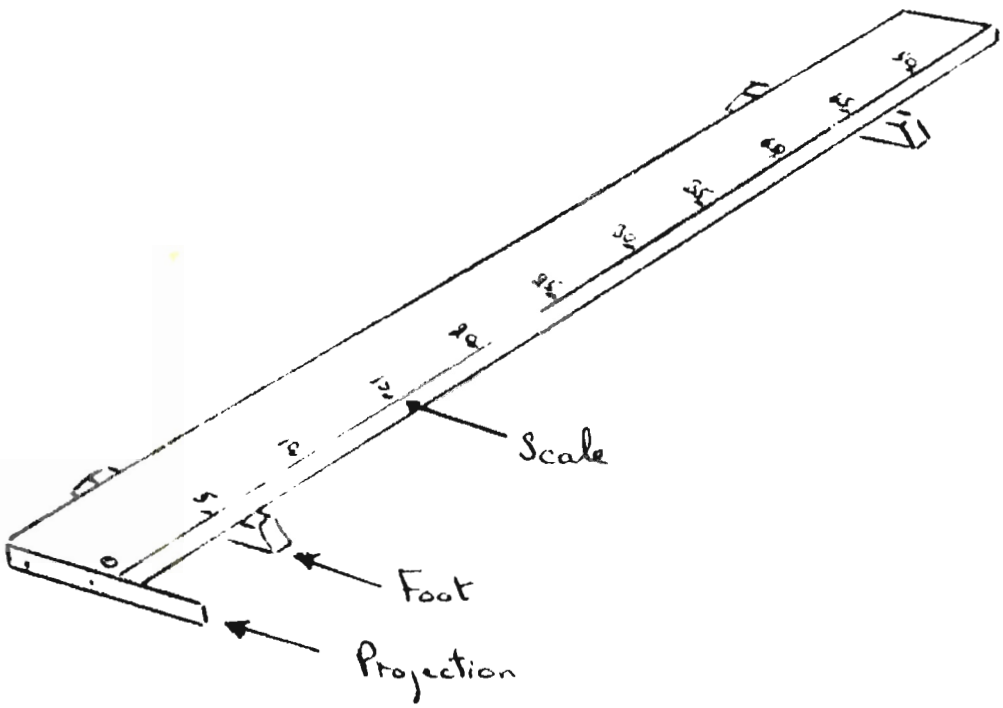
Most of the apparatus can be made with simple handtools, and students and teachers are encouraged to make items for themselves, for apparatus development can bring both students and teachers into close contact with the realities of science, relating science and technology in the simplest of ways. However, this does not mean that students and teachers should attempt to produce all their own apparatus requirements. It is recognized that teachers have specific curricula to follow, and that "class hours" available for such work are very limited. It is also recognized that teachers, particularly those in Developing Countries, are not well paid, and often augment their salaries with supporting jobs, thus placing severe limits on the "out of class hours" that are available for apparatus production. It is therefore recommended that actual production of apparatus, sufficient to meet the needs of individual schools, should be undertaken by local cottage industries. With such industries in mind a few alternative blue-prints have been added to the basic designs.

Details of related workshop facilities, methods of apparatus production, laboratory plans and overall planning are to be found in the Administrator's Guide.

1. 10.01 Triangulation Device

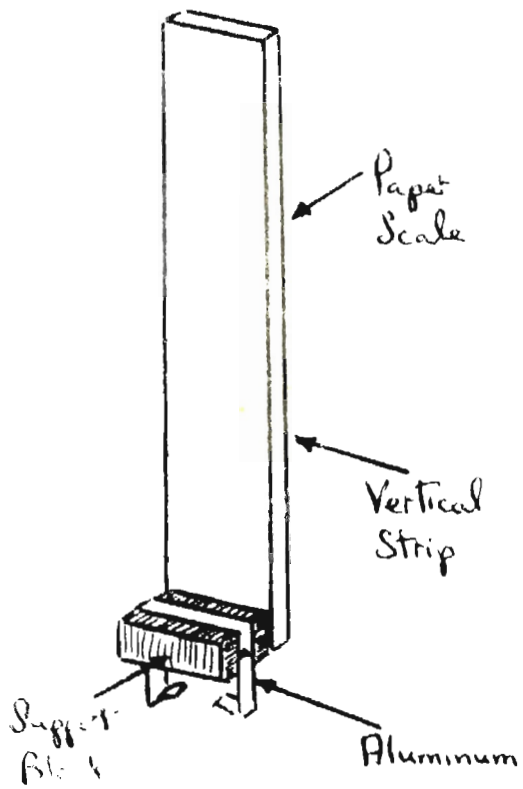


(1) Base



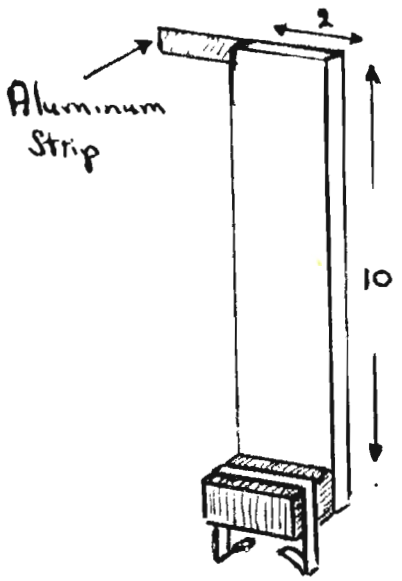
Cut a strip of wood (52 x 2 x 0.8 cms) marking a horizontal scale with 5 cm intervals along the top right edge. Make two feet from a wooden strip (5 x 1 x 0.5 cms), and attach to the lower surface of the scale about 5 cms from either end. A piece of aluminum (3.5 x 0.5 cms) attached to the near end of the horizontal scale will serve as a suitable projection.

(2) Vertical Scale



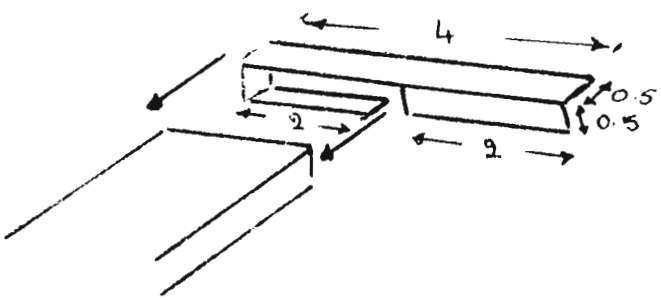
Cut a vertical strip of wood (20 x 2 x 0.8 cms) and attach a paper scale to its front surface, marking off distances every 0.5 cms from the base. Attach a support block (2 x 1.5 x 1.0 cms) to the bottom, rear surface of the vertical strip by means of glue. The vertical strip and support block should now be placed on the base, and an aluminum strip (8 x 0.5 cms) wrapped around the block, bending the loose ends into a spring shape beneath the base so as to permit the vertical scale to move freely along the base.

(3) Vertical Endpiece



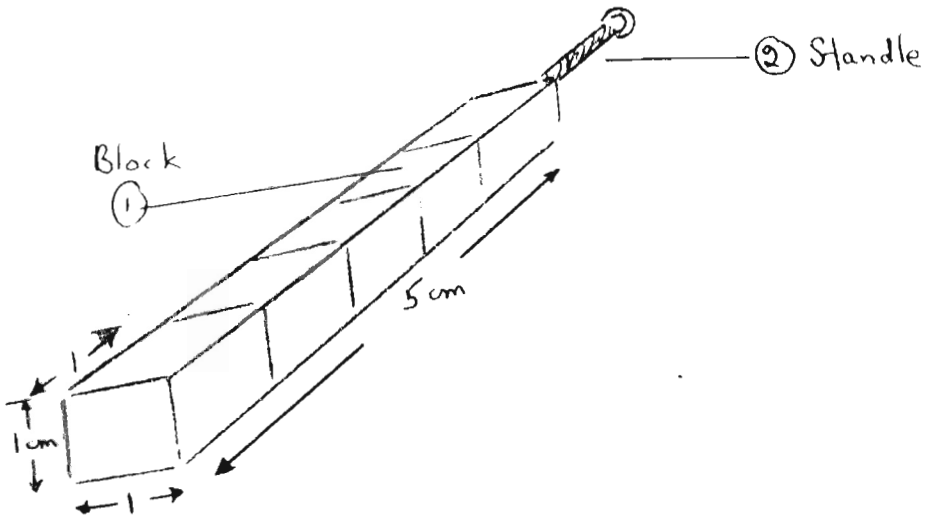
The vertical endpiece is almost a replication of the vertical scale, but with two differences. It is shorter (10 cms not 20 cms), and requires no scale markings. In addition an aluminum strip (3.5 x 0.5 cms) is attached to the top of the front surface.

(4) Sliding Projection



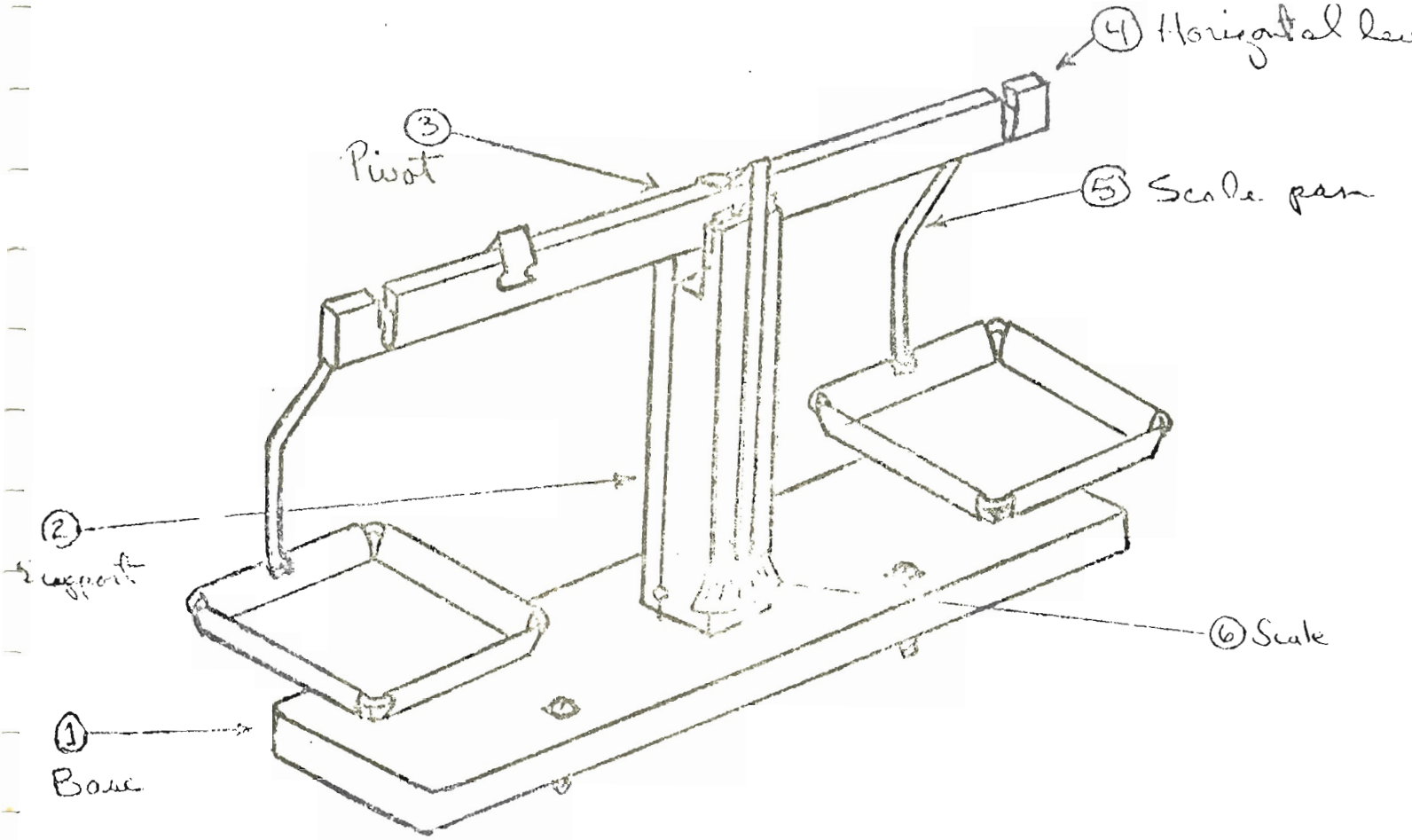
When the triangulation device is used without a vertical endpiece a sliding projection is required for sighting purposes. This may be made by cutting and bending an aluminum strip (7 x 1 cm) to slide on to the base.

1. 10/02 Displacement Block

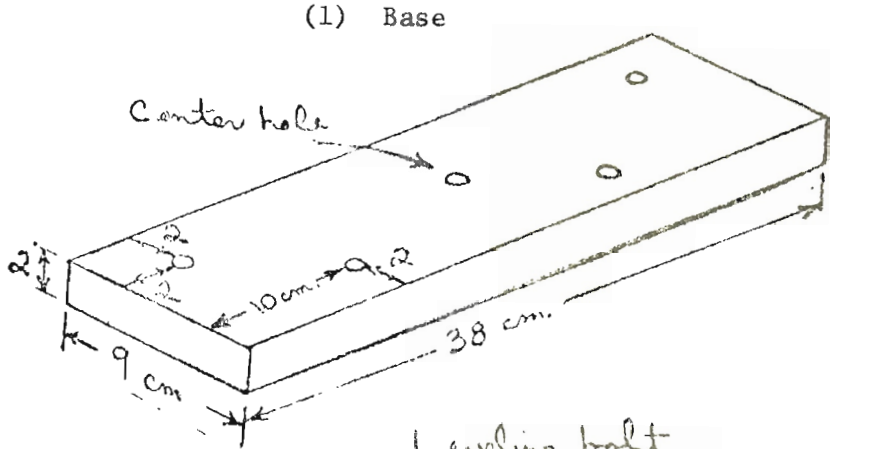


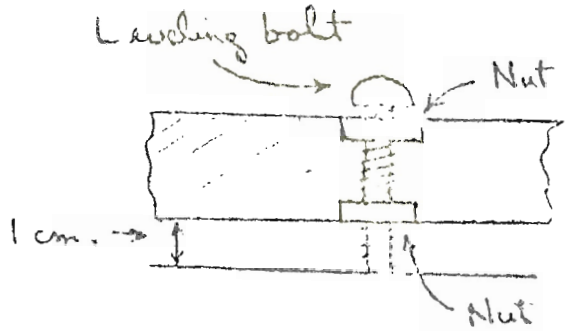
(1)	Block	A block of wood cut to the dimensions shown
(2)	Handle	A screw or nail

1. 20/01 Balance



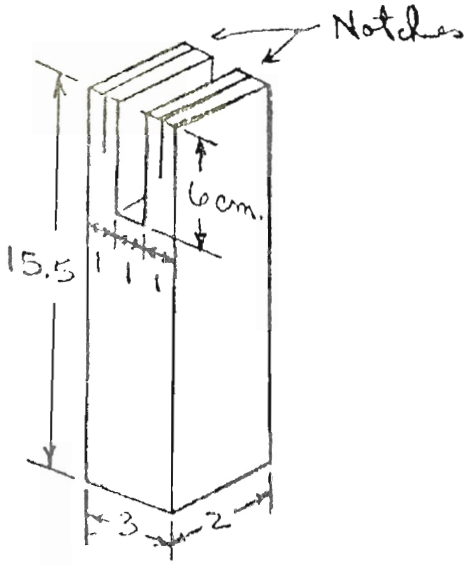
(1) Base





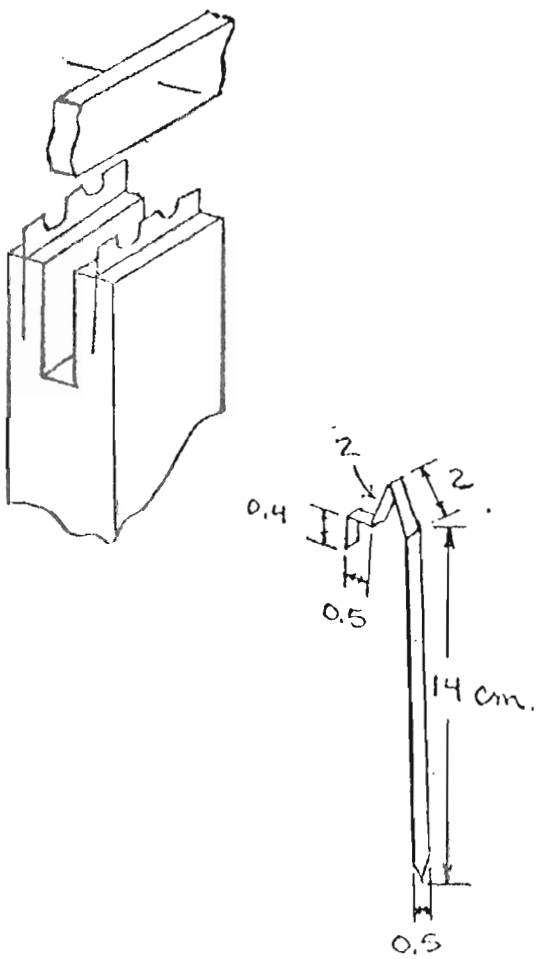
Cut the base from softwood. Drill a center hole for the support screw and four others for leveling bolts. Inset nuts into the softwood with a sharp hammer blow, and glue them in with epoxy resin. The diameter of the hole should be that of the bolt. Gluing is done with the bolt through both nuts to insure alignment. Two nuts prevent the bolt from wobbling and permit hand adjustment of the bolt.

(2) Support



Cut the support with notches at the top to receive razor blades.

(3) Pivot

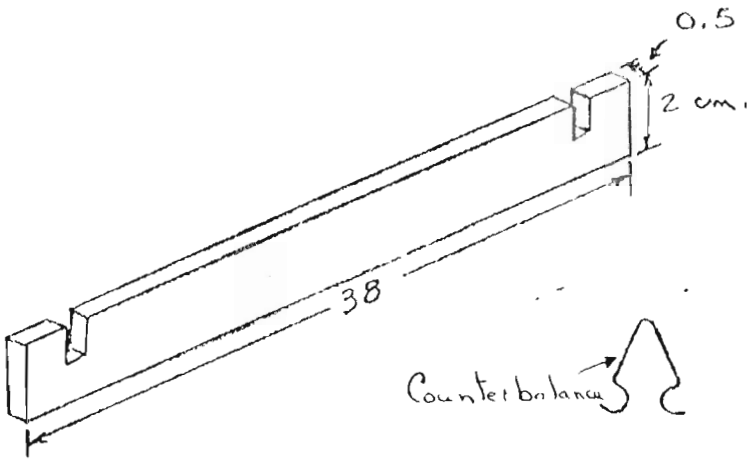


Split a razor blade in half, and glue the two halves into the slots in the top of the support. The tops of the blades should project as little as possible to reduce the strain on the blades.

Drive a steel needle 0.1 cm in diameter and 5 cm long through a hole 0.5 cm from the top of the arm and glue securely in position with epoxy, being certain it is perfectly horizontal and centered.

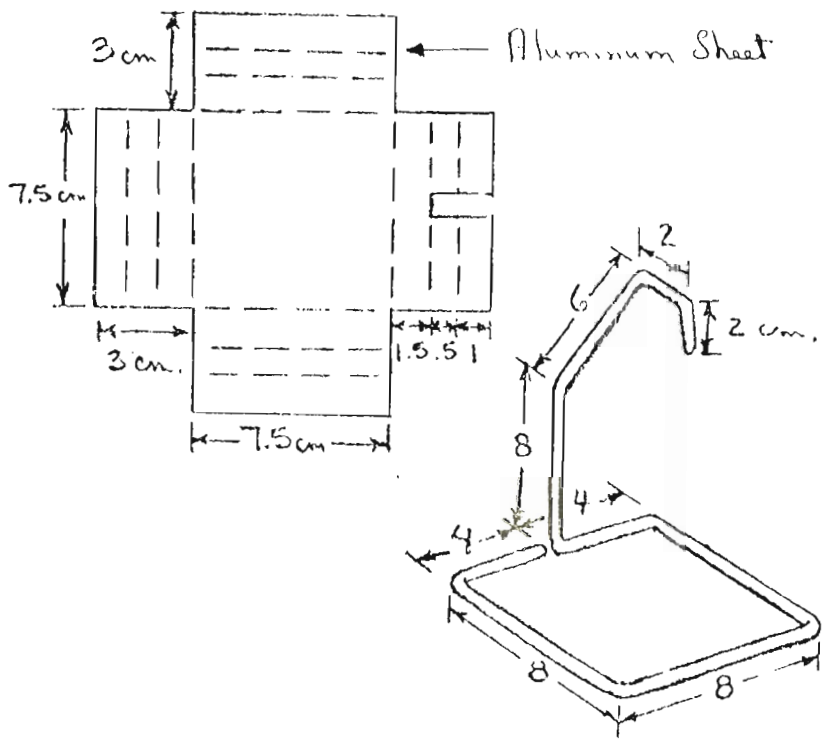
Cut the pointer from aluminum sheeting (0.05 cm thick) and bend as shown, gluing it to the arm with epoxy as close to the center as possible.

(4) Horizontal Lever



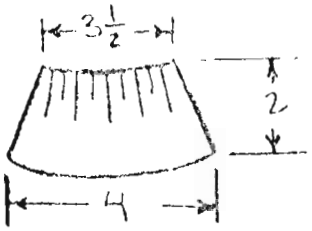
Cut the arm of the lever as shown, with notches 0.5 cm wide and 1 cm deep at 1.5 cm from the ends. For a counterbalance, bend a piece of aluminum sheet (0.05 cm thick) approximately 2 cm wide into the shape illustrated. The width of the counterbalance should be such as to prevent it from slipping on the horizontal lever.

(5) Scale Pan



Cut an aluminum sheet to the appropriate size and bend (see dotted lines) it over the pan holder framework. The gauge of the sheeting is about 0.05 cm (0.5 mm).

(6) Scale



Make a scale out of white cardboard and glue it to the support so that the tip of the pointer just reaches its top edge.

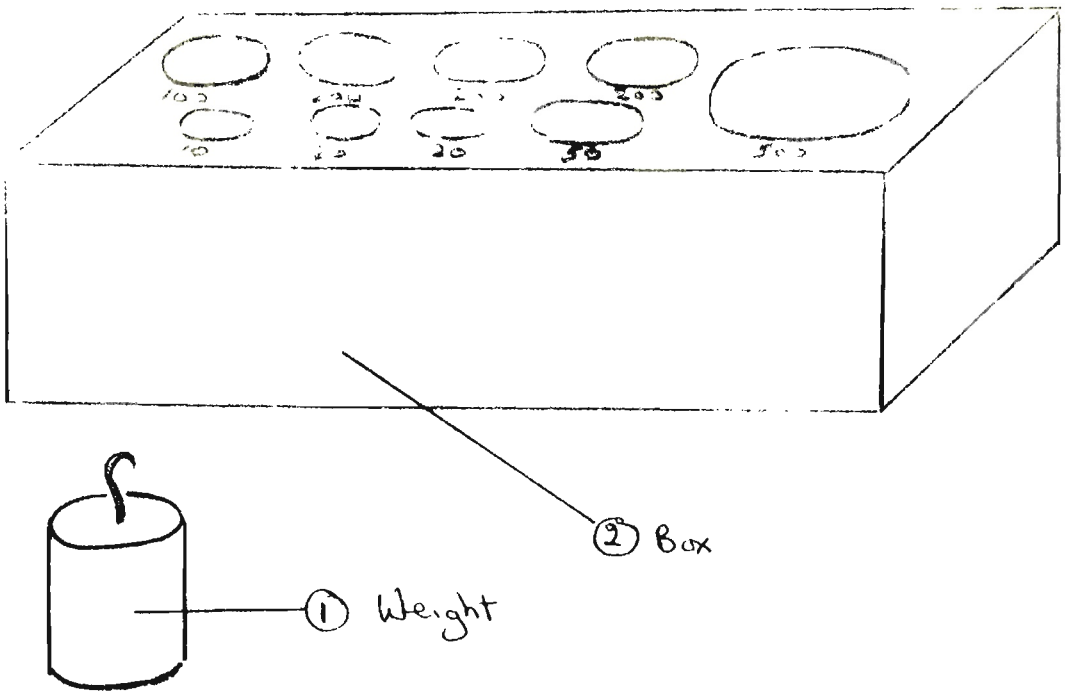
Notes

(i) The following table gives approximate values for the sensitivity of the balance under varying loads. Sensitivity is measured as the number of milligrams required to cause the pointer to move one millimeter under the given load.

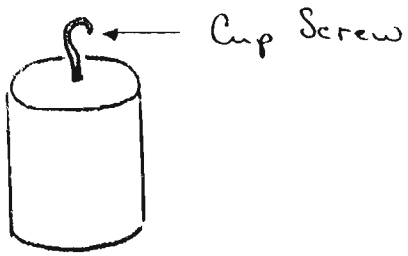
Load in Each Pan	Sensitivity
25 gms	25 mgms/mm
50 gms	25 mgms/mm
100 gms	65 mgms/mm
250 gms	200 mgms/mm
500 gms	335 mgms/mm

(ii) The centering point of the pointer is stable under varying weight loads so long as weights are placed centrally in position in the scale pans.

1. 20/02 Box of Weights



(1) Weights



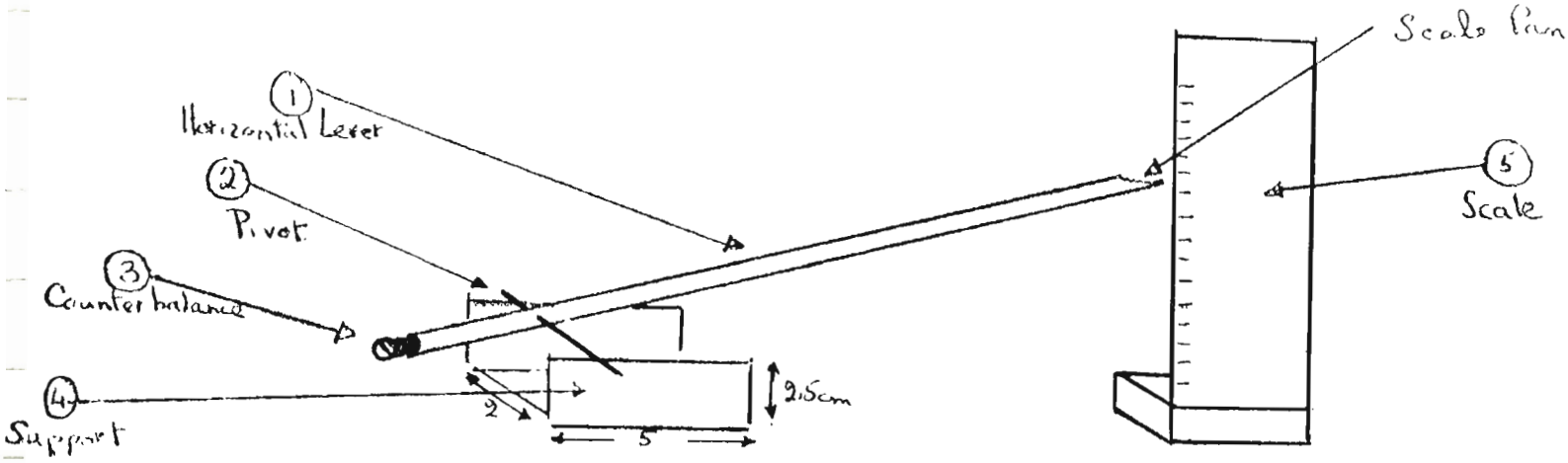
Take a box of wet sand, and use wooden dowels, or some such similar material, to make cylindrical moulds in the sand according to the dimensions given below. Heat up some lead in a can, and when it is molten pour it into the moulds. Allow the lead to solidify and cool. Then screw into the top of each lead cylinder a cup screw to serve as a handle. The lead cylinders may then be filed down until each is the desired weight. The number of weights required, and the approximate size of each mould, is indicated below.

Qu	Weight	Diam.	Depth
1	500 gm	3.8 cm	4.0 cm
3	200	2.4	4.0
1	100	2.4	2.0
1	50	2.4	1.0
2	20	1.2	2.0
1	10	1.2	1.0

(2) Box

A block of wood (17 x 8 x 5 cms) will serve as the weight holder if holes, the same size as the above moulds, are drilled into the top surface.

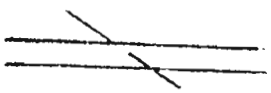
1. 20/03 Microbalance



(1) Horizontal Lever

Take a soda straw and cut one end to create a small pan for specimens (e.g., mosquitoes, flies, hair)

(2) Pivot



Push a needle through the straw close to one end. The actual position depends on the size of the counterbalance screw used.

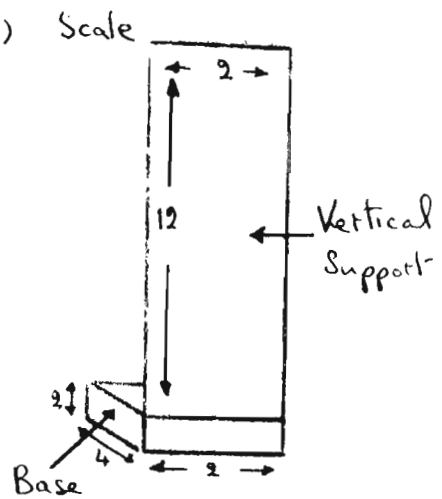
(3) Counterbalance

Take a screw which just fits into the end of the straw and adjust it to obtain a balance of the straw.

(4) Support

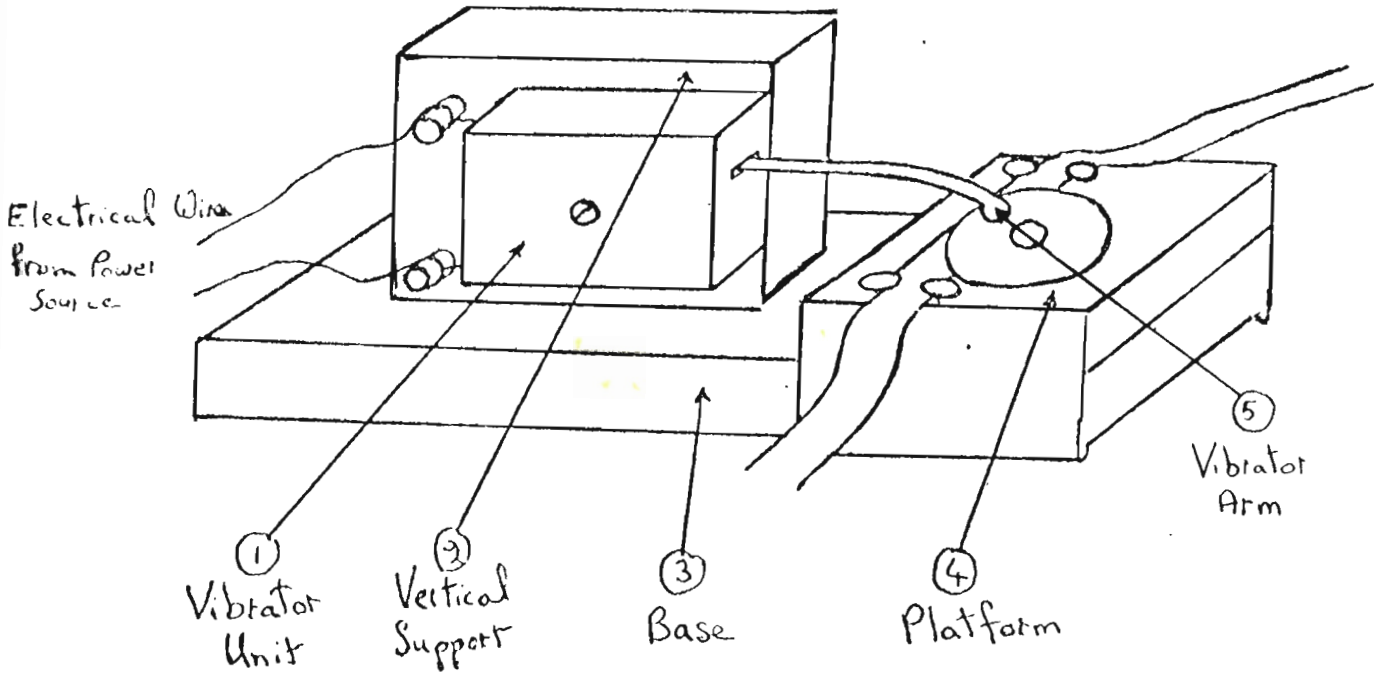
Make the support by folding a sheet of aluminum as illustrated

(5) Scale

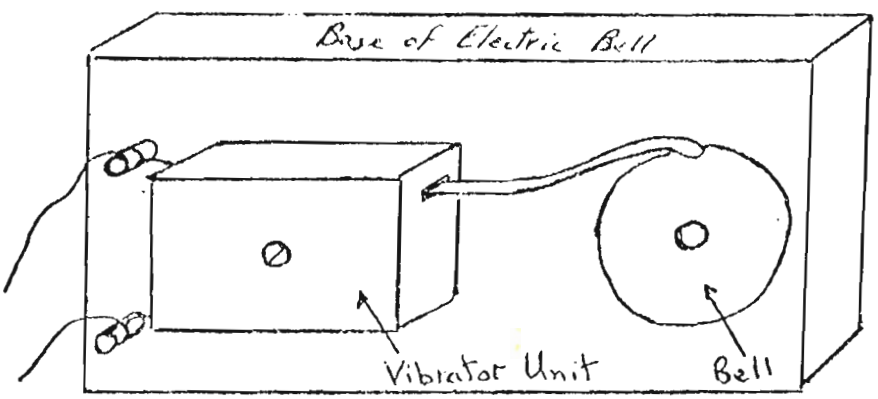


Cut a wooden block to serve as the base of the scale, and a wooden strip as the vertical support. Glue or nail the pieces together.

1. 30/01 Ticker Tape Timer

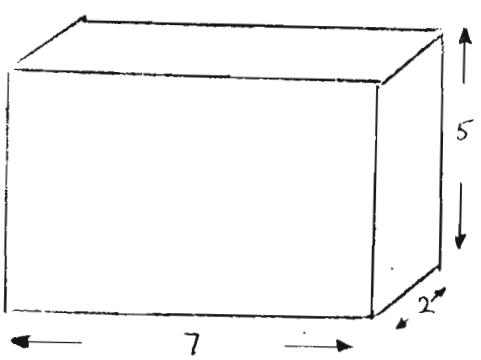


(1) Vibrator Unit



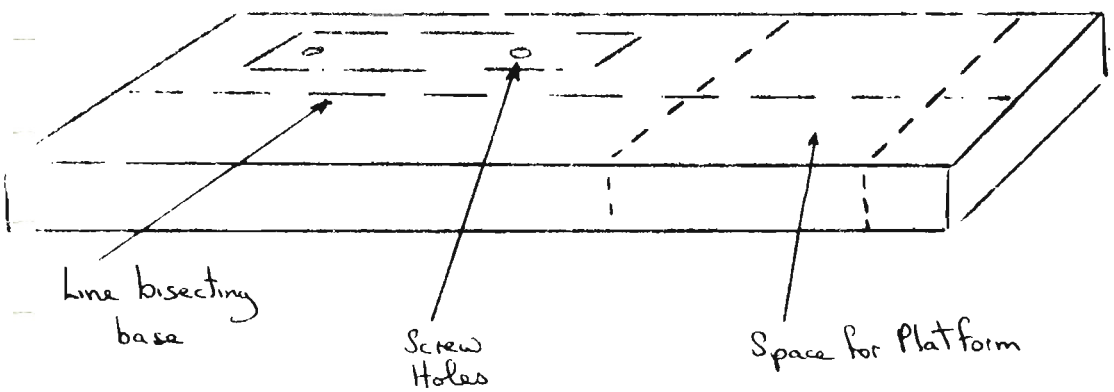
Obtain a household electric bell, and remove the vibrator unit.

(2) Vertical Support



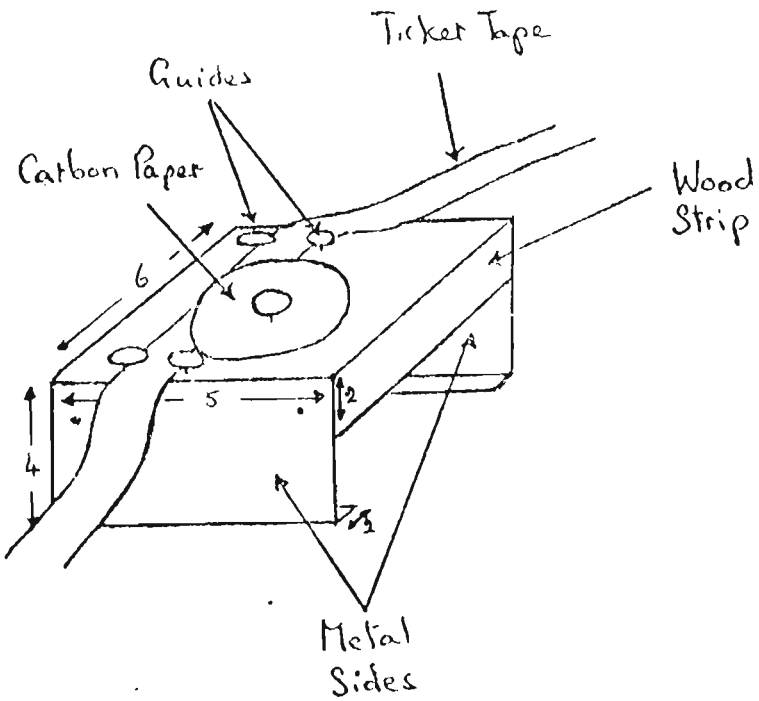
Cut a piece of wood to serve as the vertical support, and attach the vibrator unit to it with screws.

(3) Base



Cut a wooden base, approximately 16 x 6 x 2 cms. Place the vertical support on the base in such a position that the vibrator arm will be parallel to, and directly above, the line bisecting the length of the base. Mark in the position of the support, and then drill two appropriate holes in the base so as to facilitate the attachment of the support with screws.

(4) Platform

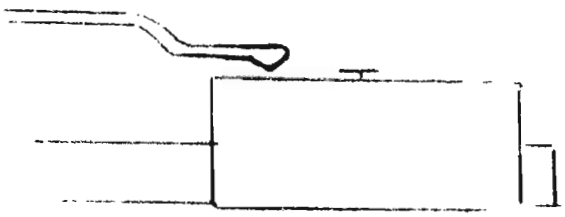


Cut the platform from hard wood and the side pieces from aluminum. Attach the side pieces to the platform with nails, then with the platform in position on the base bend the side pieces at the bottom to hold the platform firmly in contact with the base. (A loosely fitting platform will result in a poor track being recorded on the ticker tape).

Cut a circular disc out of carbon paper, and pierce the center so that it may pivot freely about a thumb tack in the center of the platform.

Pin four more thumb tacks in the platform to serve as guides for the ticker tape which must pass under the carbon disc. There must be negligible friction between the guides and ticker tape.

(5) Vibrator Arm

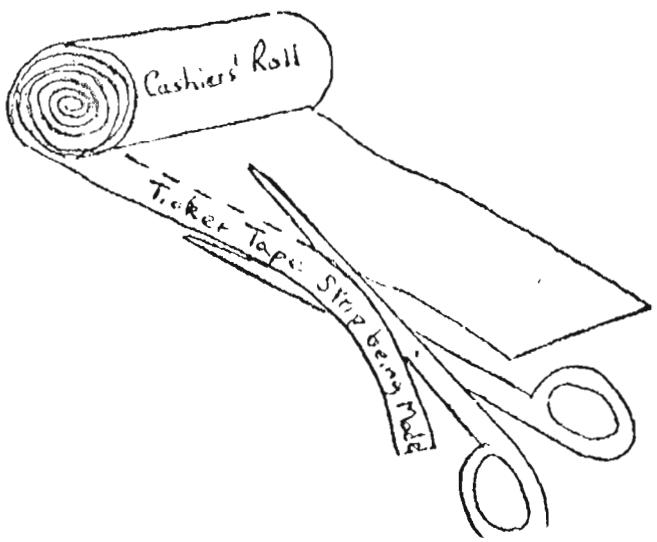


Bend the vibrator arm downwards so that the endpiece is within 3 or 4 mms of the platform surface.

Notes

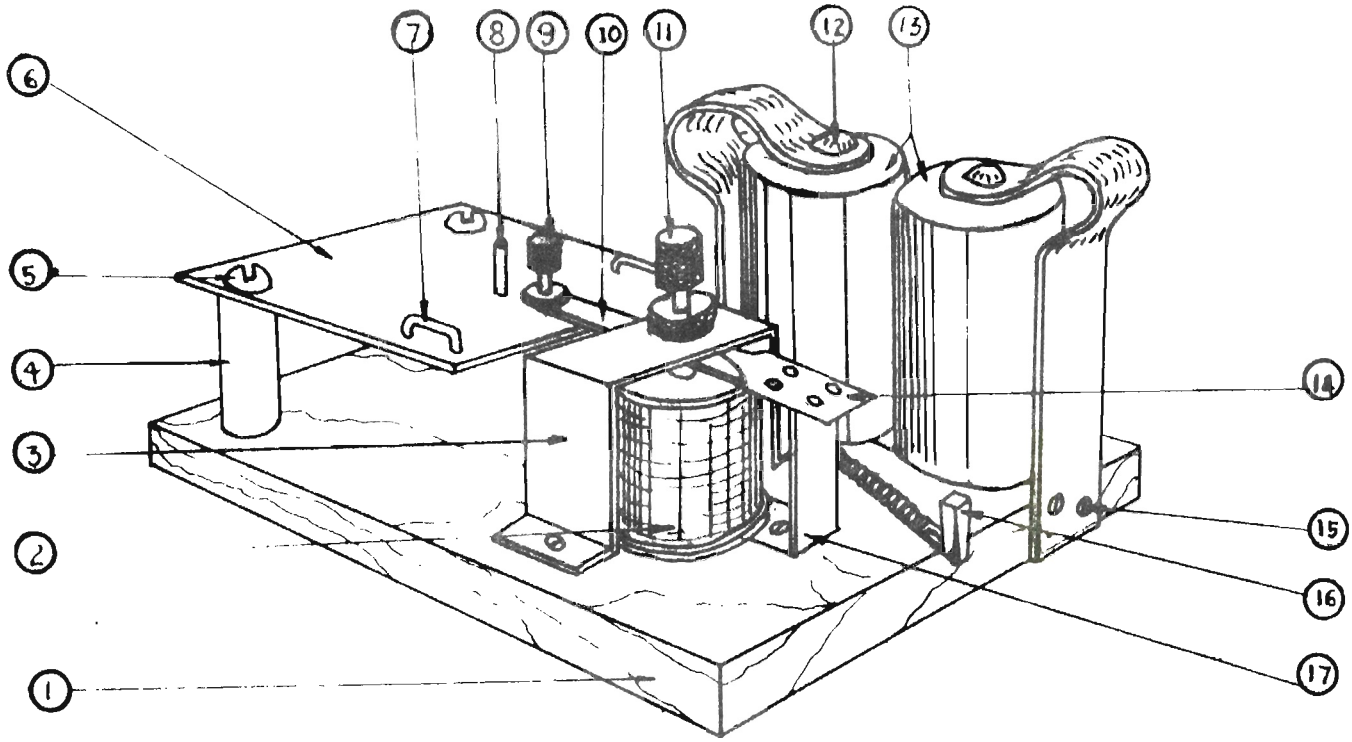
(i) Most household bells (and hence the modified timer) are designed to operate on about 10 volts. However, 2 dry cells in series will generally operate the timer.

(ii) If ticker tape is difficult to obtain, cashiers' paper rolls (for cash registers) are generally available, and may be cut into strips of suitable width, so long as care is taken to obtain smooth straight edges.



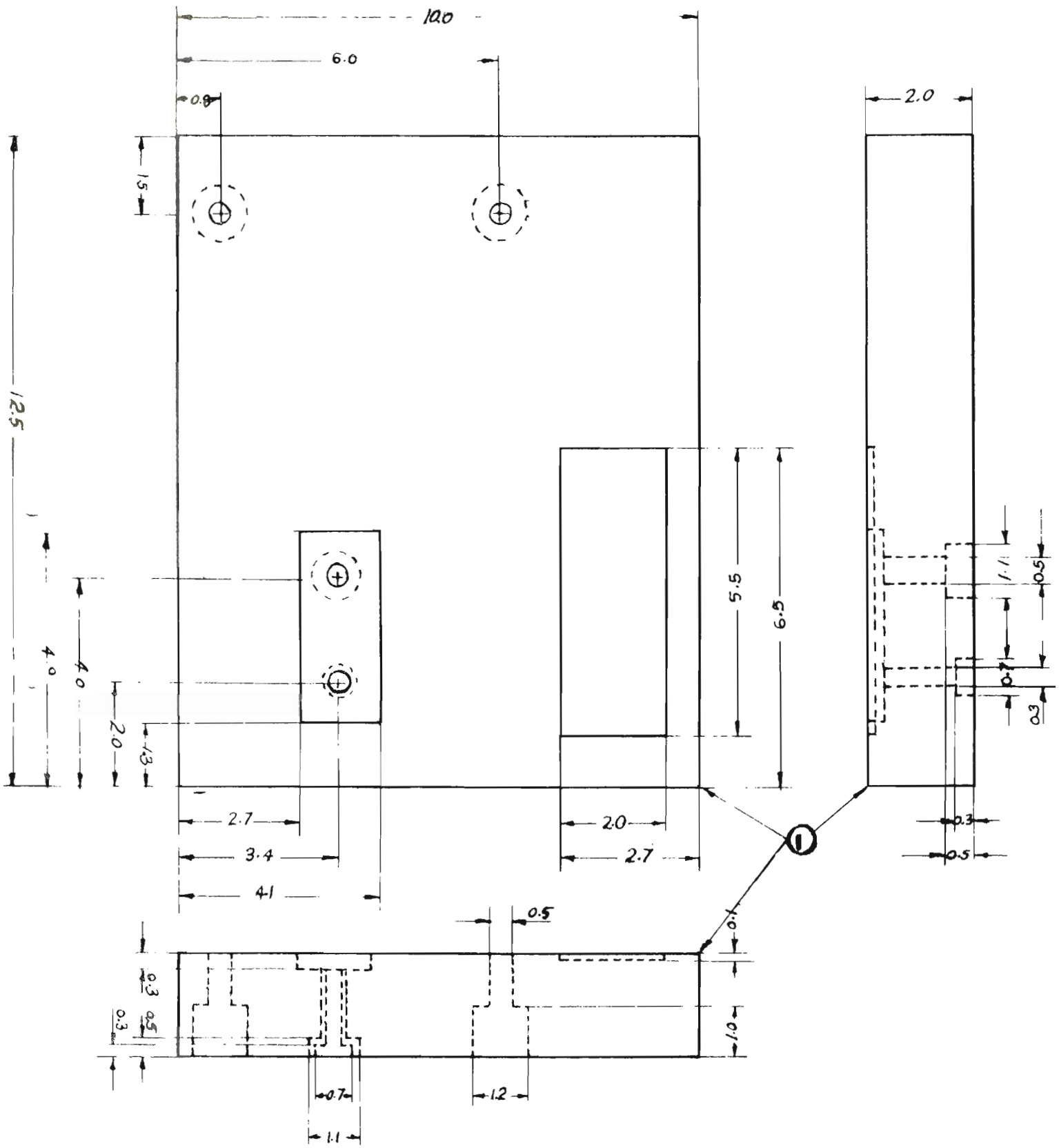
(iii) For those with some technical knowledge, wishing to produce the timer in its entirety (vibrator unit included) an "alternative ticker tape timer" design is presented in the form of technical drawings.

1. 30/02 Alternative Ticker Tape Timer

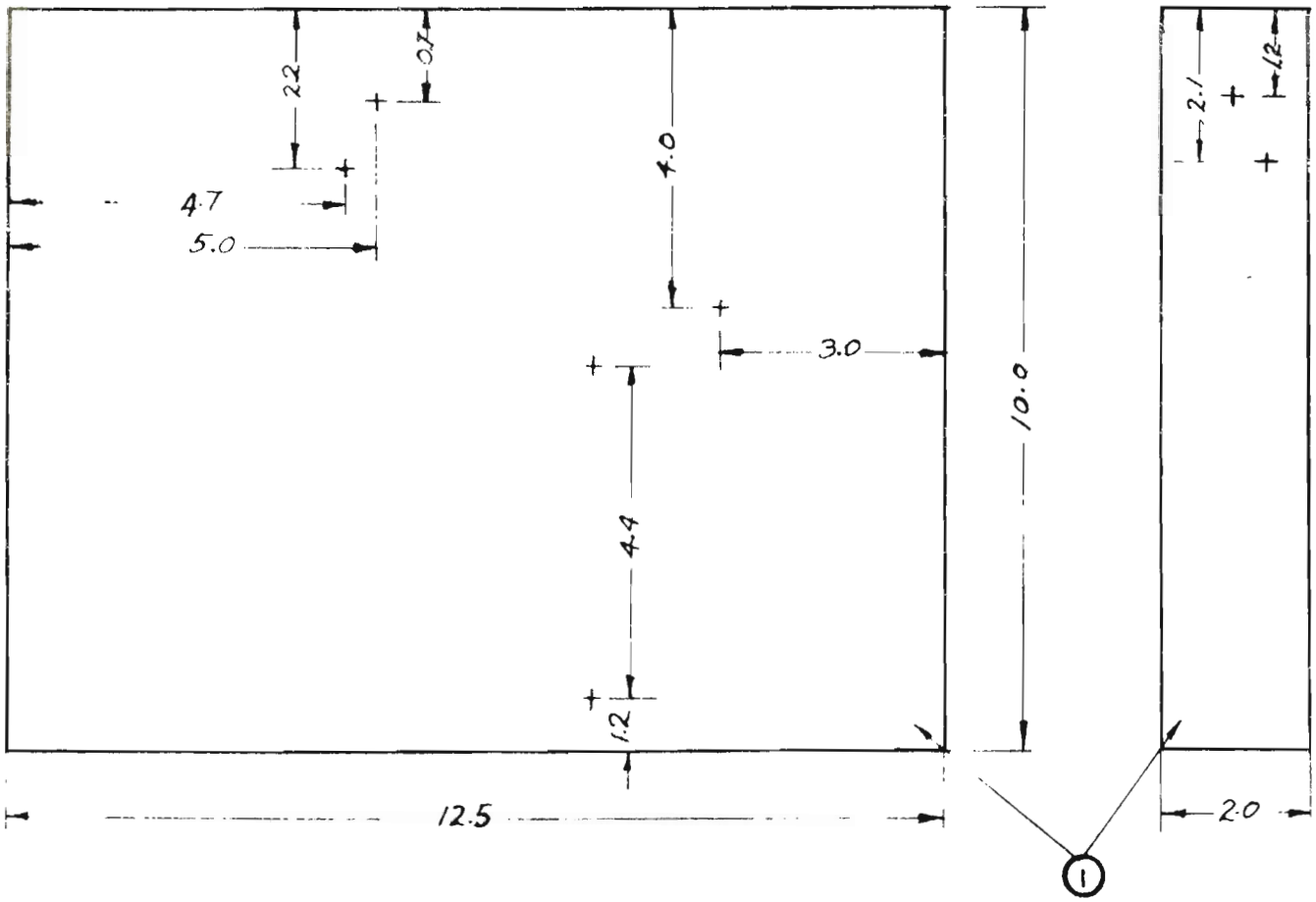


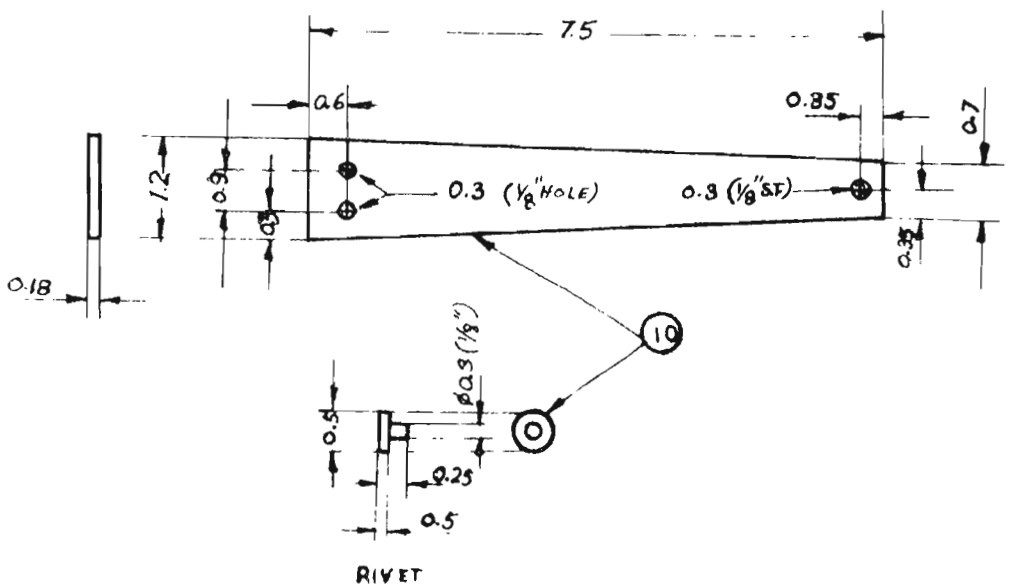
TICKER TAPE TIMER

PART NO.	DESCRIPTION	DIMENSION	QUANTITY
1	BASE - (NARRA) WOOD	20X12.5X10.0	1
2	COIL and CORE - MAGNET WIRE - SOFT IRON	NO 26 (53X3.0)	1
3	BRIDGE - BRASS	0.18X1.3 X14.0	1
4	BRASS SUPPORT	Ø0.8X2.5	2
5	STEEL BOLT	0.45X1.9 (3/16ST x 3/4")	4
6	BRASS TABLE	0.18X5.0X6.6	1
7	TICKER TAPE GUIDE	Ø0.18X2.0	2
8	CARBON HOLDER	Ø0.33X1.2	1
9	TICKER TAPE SCREW W/ NUT	Ø0.64X1.9 (1/4 x 3/4")	1
10	VIBRATING ARMATURE	0.18X6.0X6.6	1
11	CONTACT SCREW W/ NUT	1.0X2.5	1
12	BATTERY HOLDER	0.07X1.7X13.0	2
13	BATTERY	Ø3.31X6.2 (1.5 VOLTS)	2
14	CONTACT SPRING - BRASS SHEET	0.05X4.4X1.2	1
15	WOOD SCREW	Ø0.47X1.2	7
16	SWITCH	0.18X0.44X4.5	1
17	ARMATURE SUPPORT	0.18X1.5X8.45	1

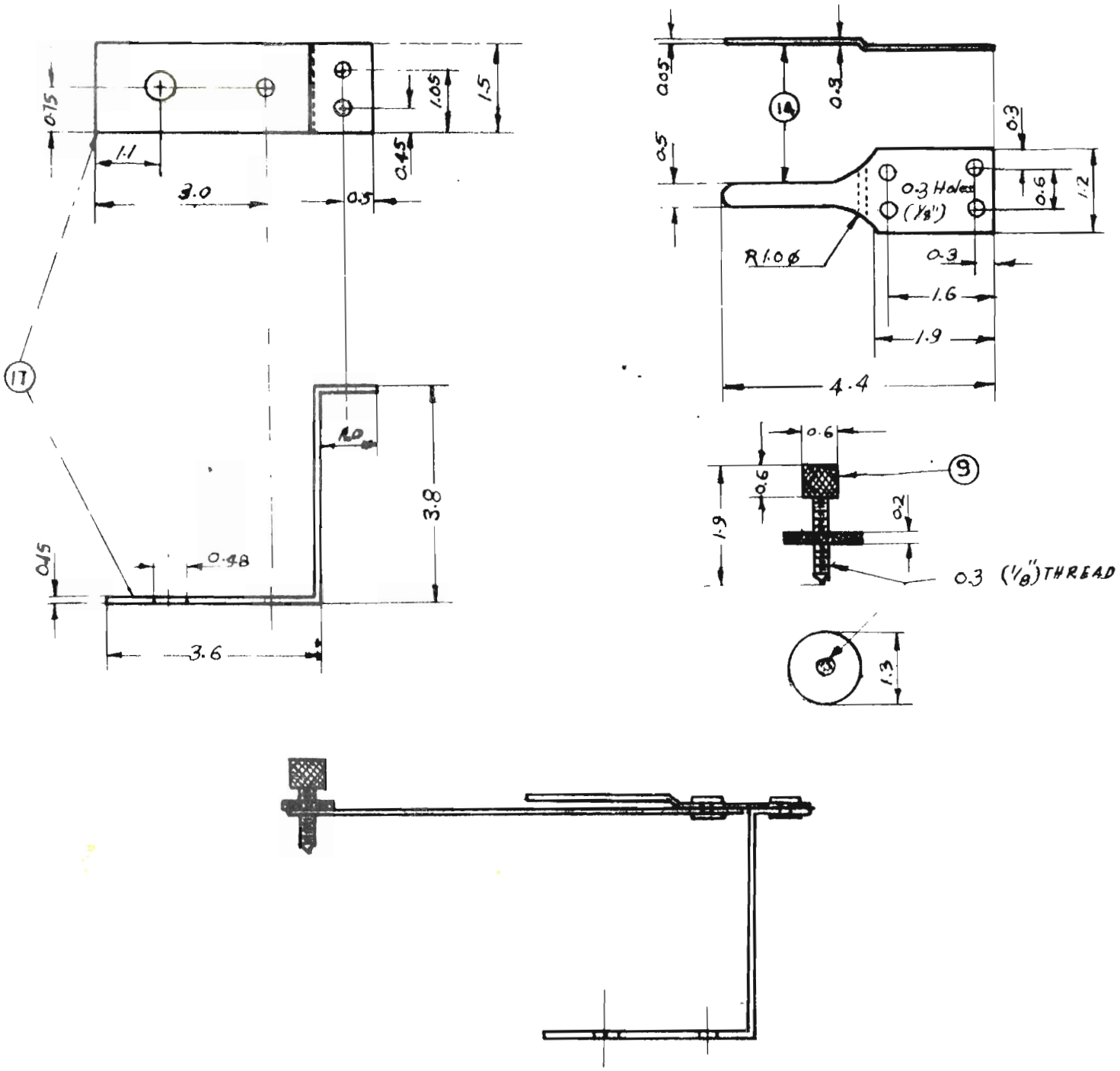


PART NO.	TICKER TAPE TIMER PARTS -1-	SCALE
1	BASE - (NARRA) WOOD	1:1

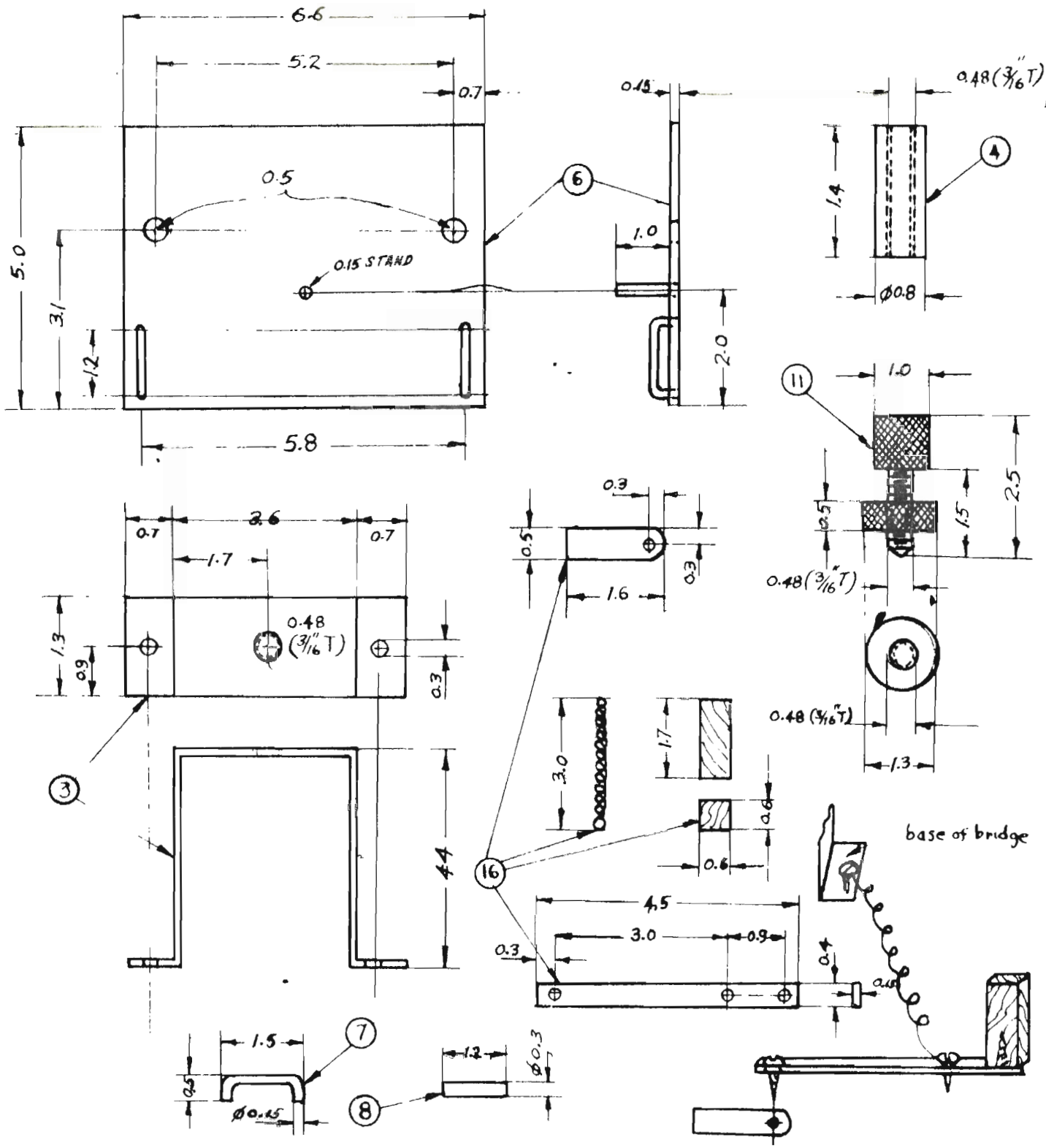




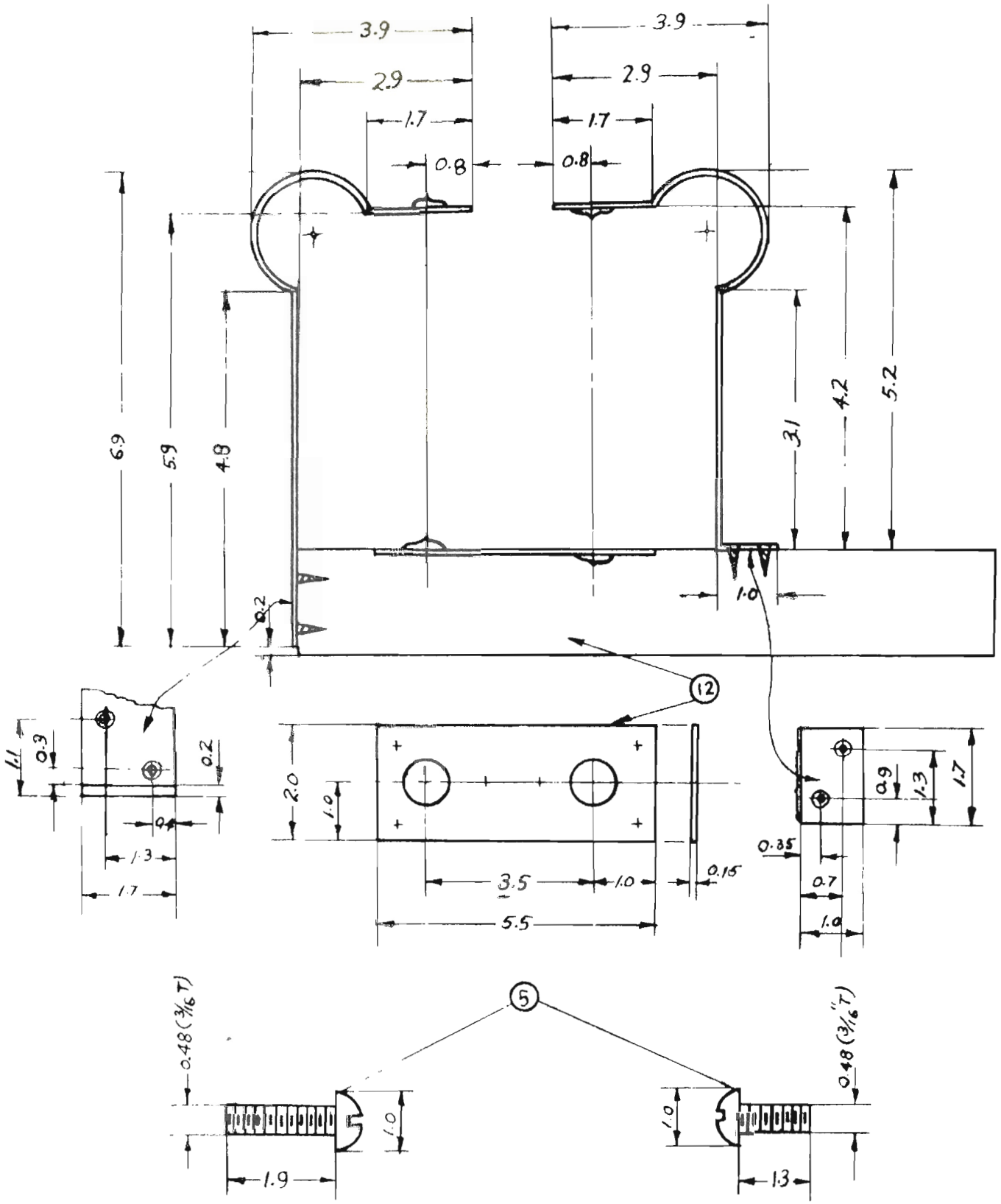
PART NO.	TICKER TAPE TIMER PART 1-10	SCALE
1	(NARRA) WOOD BASE (+ WOOD SCREW LOCATION)	1:1
10	MILDSTEEL SHEET	1:1
	4 PCS BRASS RIVIT	1:1



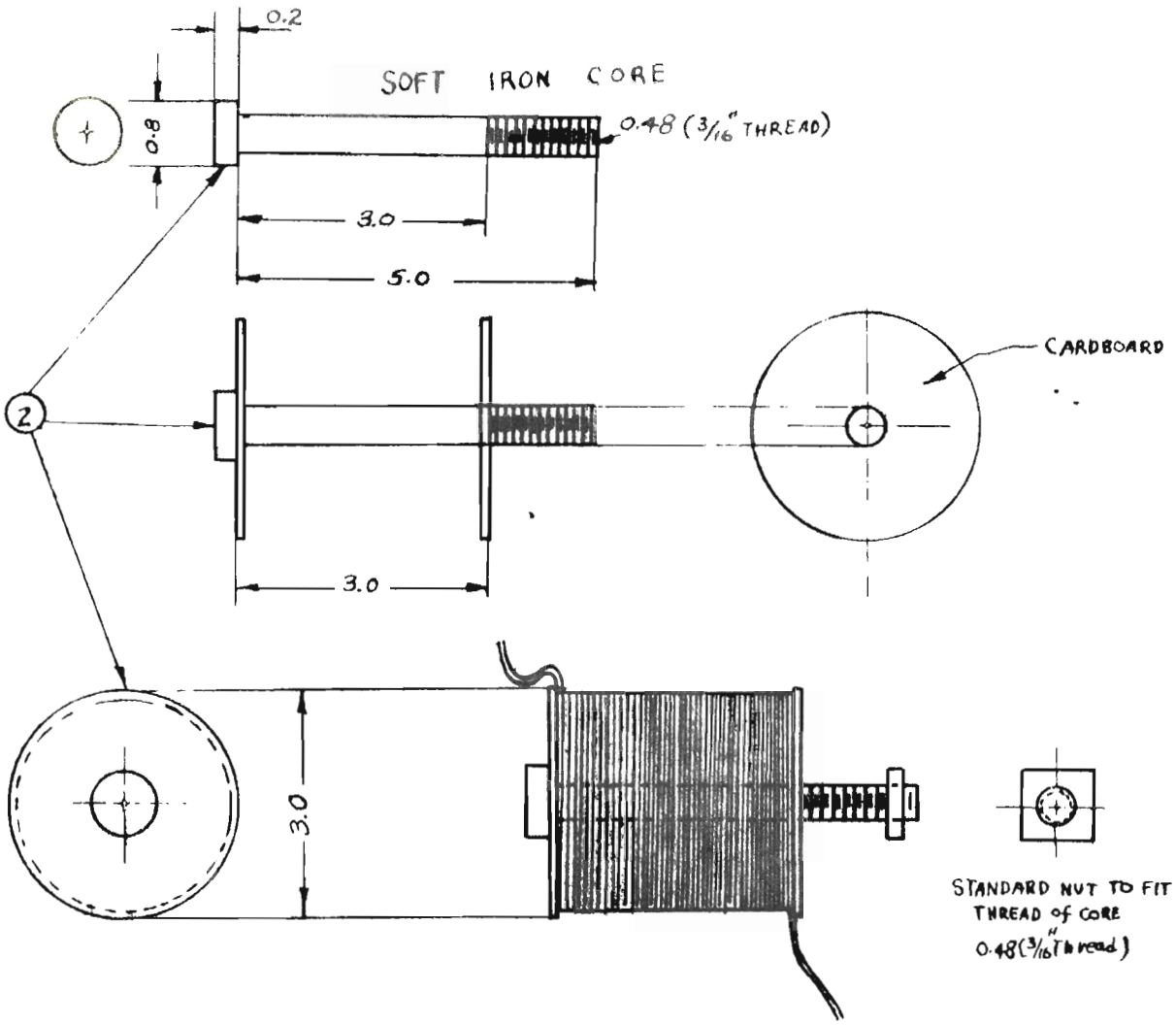
PART NO.	TICKER TAPE TIMER PARTS 9-14-17	SCALE
9	TICKER TAPE SCREW w/ NUT - BRASS	1:1
14	VIBRATING ARMATURE - MILD STEEL SHEET	1:1
17	CONTACT SPRING - BRASS SHEET	1:1



PART NO.	TICKER TAPE TIMER PARTS -3-4-6-7-8-11-16	SCALE
3	BRASS BRIDGE	1:1
4	BRASS SUPPORT	1:1
6	BRASS TABLE	1:1
7	TICKER TAPE GUIDE	1:1
8	CARBON HOLDER	1:1
11	CONTACT SCREW W/ NUT	1:1
16	SPIRAL SPRING - MUSIC WIRE	1:1
16	SWITCH	1:1



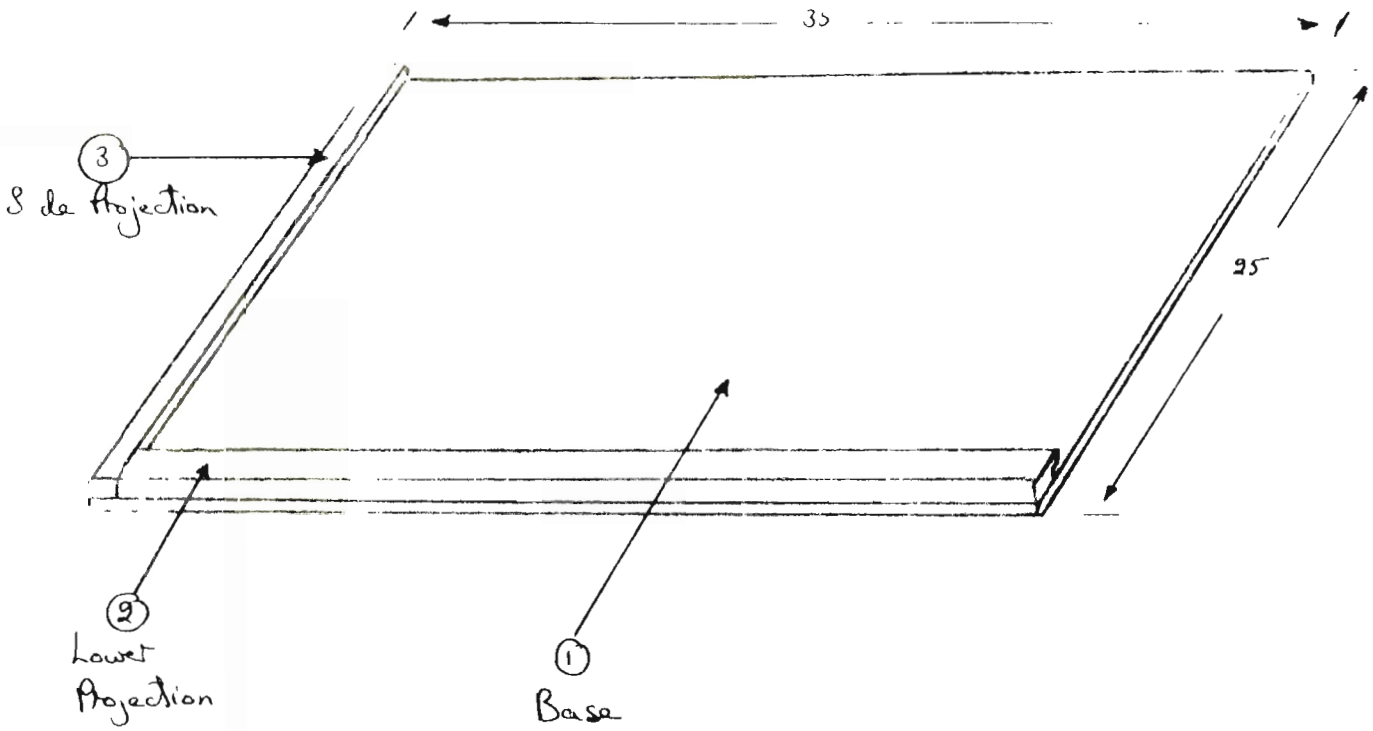
PART NO	TICKER TAPE TIMER PARTS -5-12-	SCALE
5	BATTERY HOLDER - BRASS	1:1
12	2 BOLTS (LONG), 2 BOLTS (SHORT), BRASS	1:1



NOTE: COIL IS # 26 MAGNET WIRE WITH A 6 OHM RESISTANCE, TWO WIRES WOUND IN PARALLEL

PART NO	TICKER TAPE TIMER PART -2-	SCALE
2	COIL and CORE	1 1
"	SOFT IRON CORE W/ NUT	1 1
- " -	CARDBOARD 0.15 (1/16")	1.1
- " -	MAGNET WIRE #26	1.1

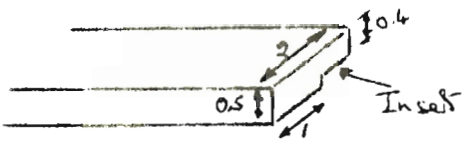
1. 40/01 Relative Motion Frame



(1) Base

Cut the base out of hardboard or plywood (35 x 25 x 0.5 cm).

(2) Lower Projection

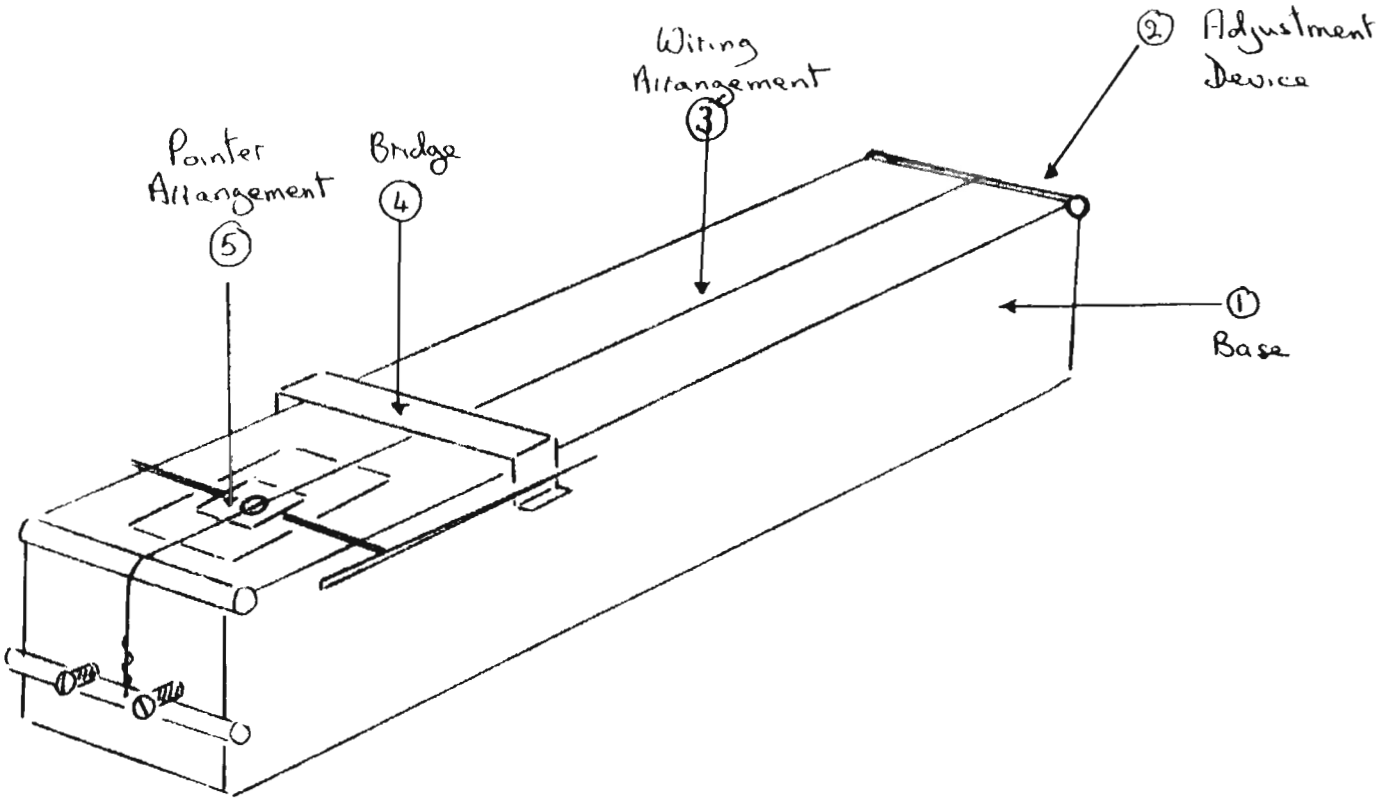


Take a strip of wood (34 x 2 x 0.5), and cut an inset (1 x 0.1) along the bottom far edge, so that when the strip is glued to the base the inset will make a groove between the projection and base.

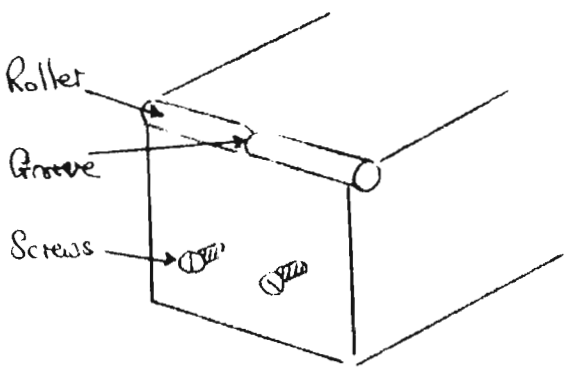
(3) Side Projection

Cut a strip of wood (25 x 1 x 0.5), and glue to the base as shown.

2.10/01 Wire Extender



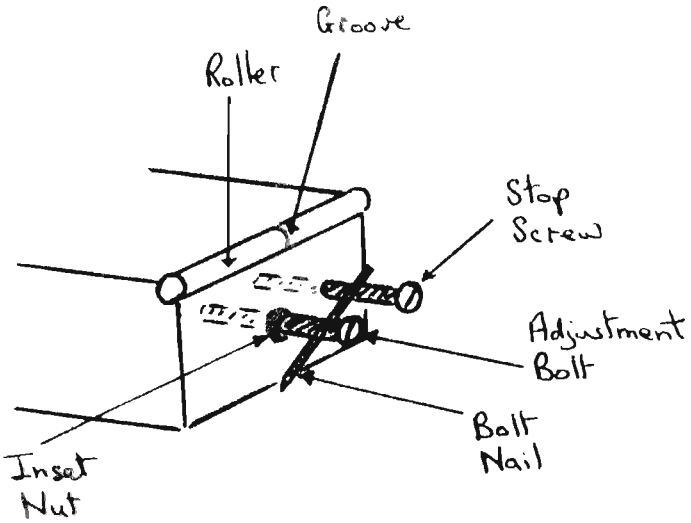
(1) Base

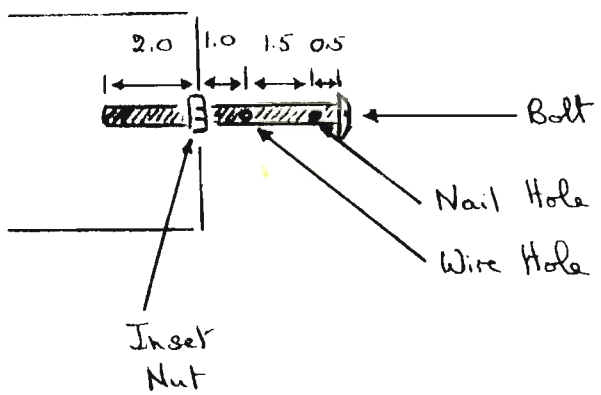


Cut the base out of wood (85 x 4 x 4 cms). Make an inset along the top of both of the end-pieces, and glue a metal roller (a cut off nail, 0.7 cm in diam.) firmly in each inset using expoxy resin. File a small groove in the middle of each roller to contain the extension wire in position.

Insert two screws about 3 cms apart at the same height in one of the endpieces to maintain the wireholder in position.

(2) Adjustment Device





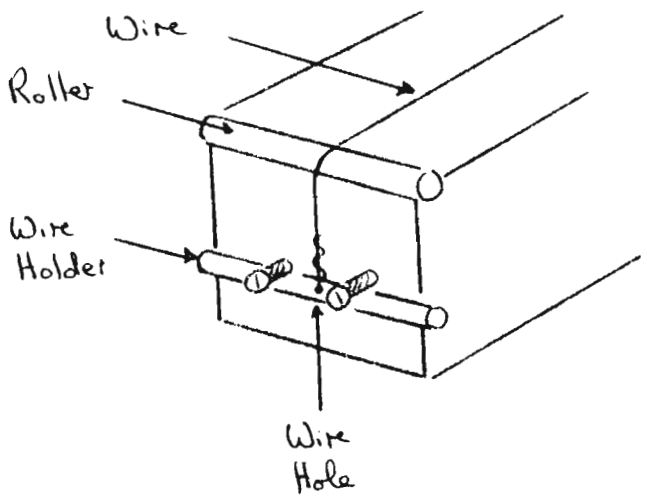
Bore a hole (0.7 cm diam., 3 cm deep) into the center of the other endpiece. Then take the nut from a suitable nut and bolt combination (6 cm long and 0.7 cm diam.), and inset it over the hole by tapping it sharply into the wood with a hammer.

Now drill two holes through the bolt, a nail hole (0.3 cm diam.) 0.5 cm from the bolt head, and a wire hole (0.05 cm diam.) 2 cms from the bolt head. (A drill press will be essential for this process.)

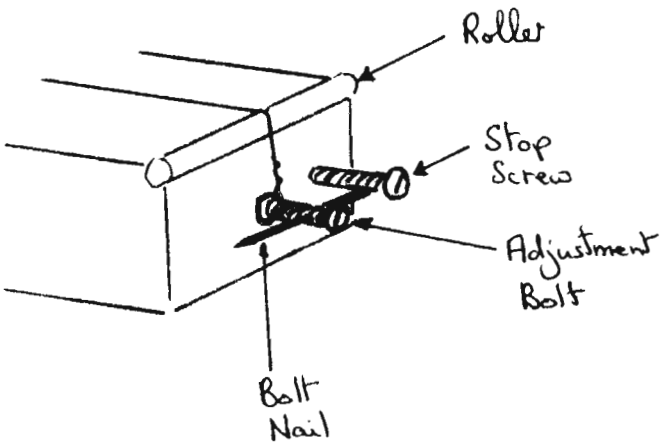
A nail (5 cms long, 0.2 cms diam.) may then be inserted through the appropriate bolt hole, which should be large enough to permit the nail to slide freely in and out.

A screw of approximately the same length as the bolt should be inserted into the endpiece at the same height as the bolt, but as far to the side of it as possible, to serve as a stop screw.

(3) Wire Arrangement

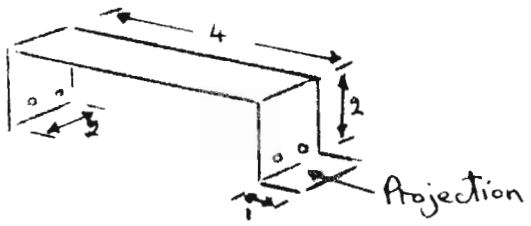


Cut a nail (10 x 0.7 cms) down to 7 or 8 cms to serve as the wire holder, and drill a hole through its center to take one end of the wire (100 cms of #26 steel wire). Attach one end of the wire to the holder, and pass the other end over the base to the adjustment bolt, making sure that the wire sits in the groove of each roller.



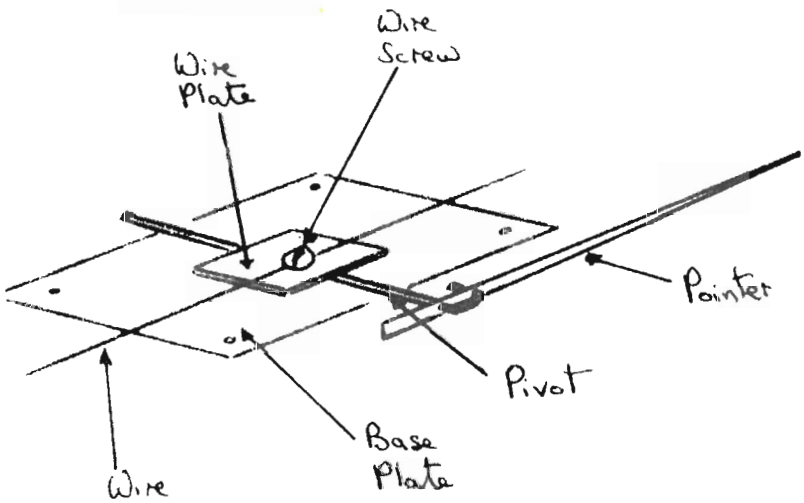
Fasten the end of the wire to the adjustment bolt by means of the appropriate wire hole, and take up the slack in the wire by turning the bolt. The latter can then be held in a set position by lodging the bolt nail beneath the stop screw.

(4) Bridge



Cut and bend the bridge from aluminum sheeting, and attach it to the top surface of the base (with small nails) about 10 cms from the wire holder end. The bridge is intended to provide some protection should the wire break, and one might in fact prefer a second bridge close to the middle of the base. The projection from the bridge also serves as a rest, and zero position, for the pointer.

(5) Pointer Arrangement



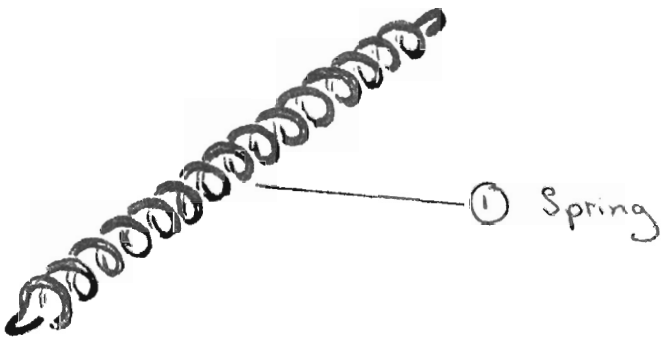
Attach an aluminum base plate (5 x 3 x 0.1 cms) to the top surface of the base about 2 cms from the endpiece to which the wire holder is attached.

Cut a small wire plate (2 x 2 x 0.1 cms) from aluminum or brass, and thread a hole in the center to take a small bolt. Once the bolt has been screwed into the hole cut off the protruding end beneath the plate, so that when the plate is attached to the wire, the bottom surface is always smooth.

The pivot may be an aluminum or brass rod (6 cms long, 0.15 cm diam.) bent at the end to prevent the pointer from slipping.

Cut the pointer (13 cms long) from cardboard, and attach to the bent end of the pivot with scotch tape.

2.10/02 Wire Spring



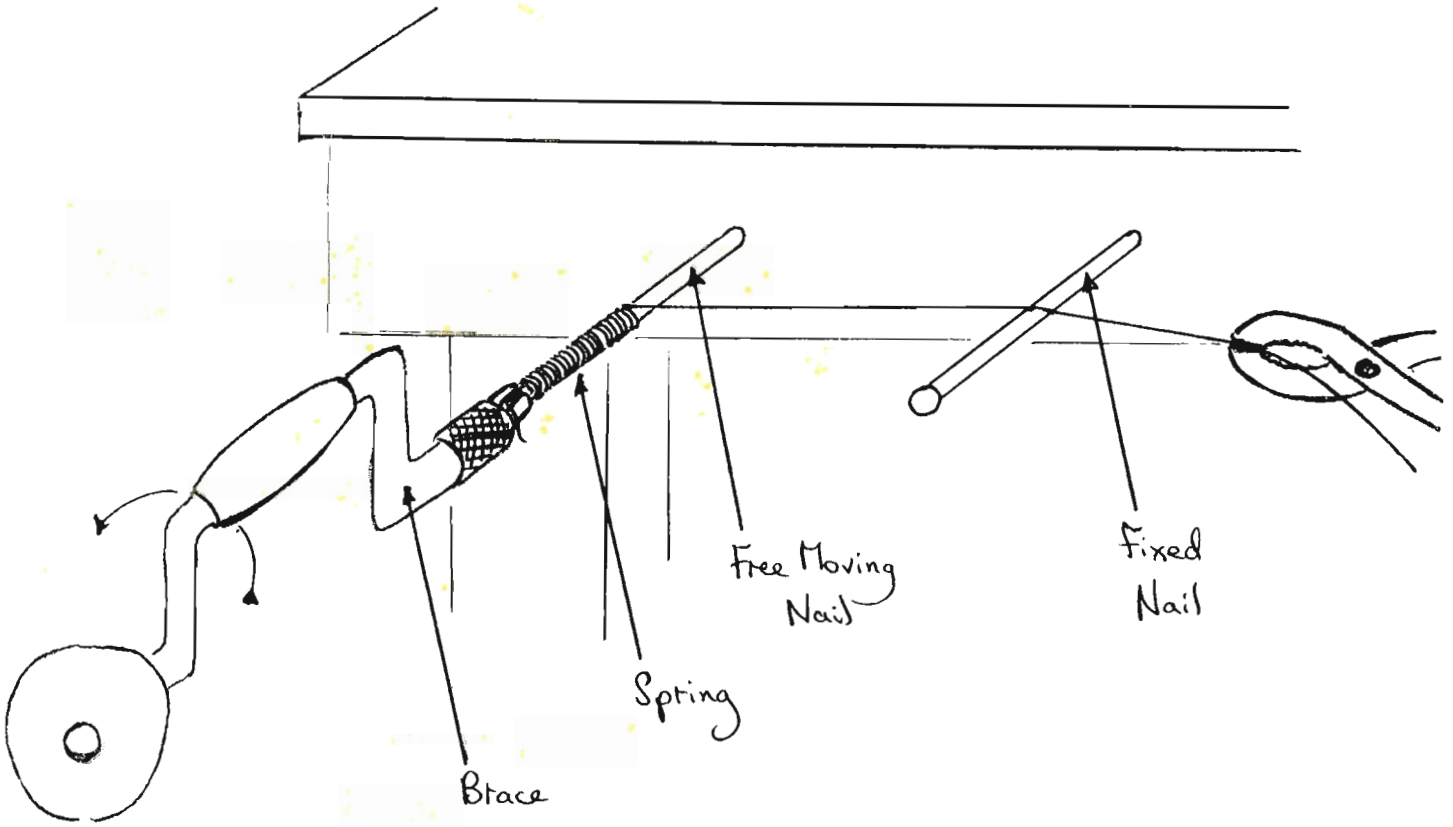
(1) Spring

Approximately 40 cms of steel wire (#26, approximately 0.07 cms diam.) should be sufficient to make a spring about 10 cms long and 1 cm in diameter.

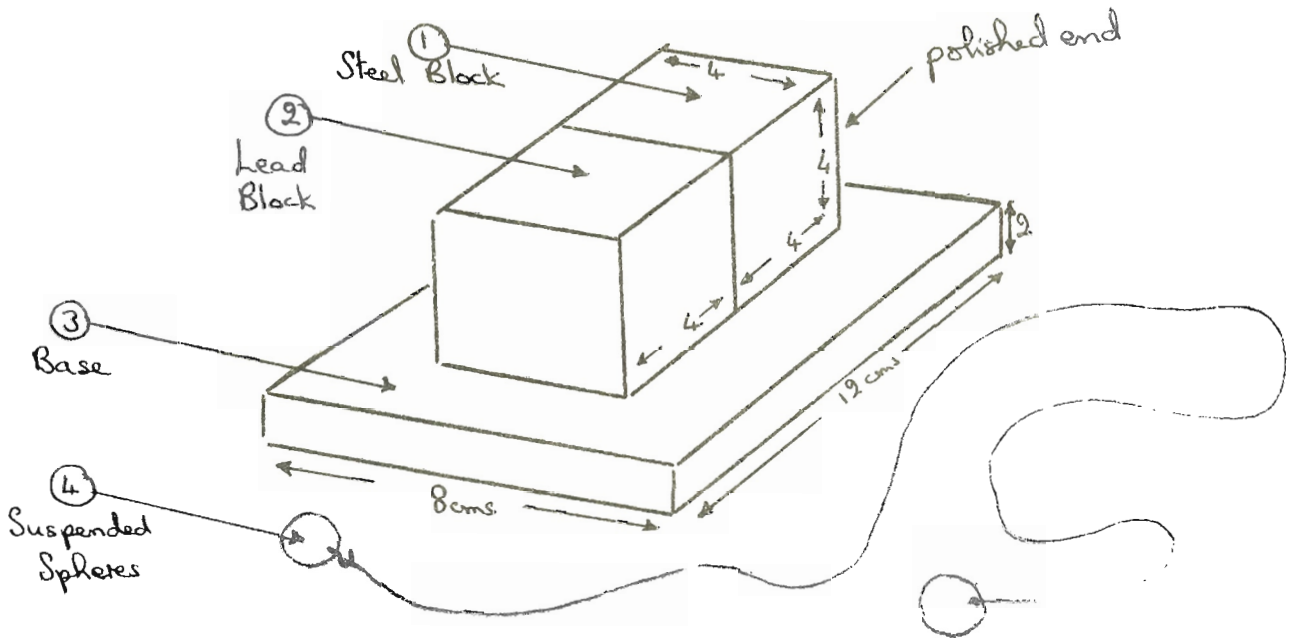
The most important factor in winding the spring is to keep the wire taut at all times, and for this the help of a brace and two nails (10 cm) is invaluable. Drill a horizontal hole about 3 cms deep in the bench for the free moving nail, and about 20 cms to the right of this drive in a second (fixed) nail. Clamp one end of the wire, along with the head of the free nail in the jaws of the brace, and get your partner to hold the other end of the wire in the jaws of a pair of pliers, keeping the wire taut with the assistance of the fixed nail. Turn the brace, winding the wire firmly around the free nail. The spring may be close wound (each turn touching the next) or open wound (each turn separated from the next by a fixed distance). Although the wire is wound on a nail of diameter 0.7 cms, on release from tension it

it will tend to expand to about 1 cm diameter.

(A spring made from a more plastic material such as copper wire can be made much more easily, simply by winding the wire onto the nail by hand.)



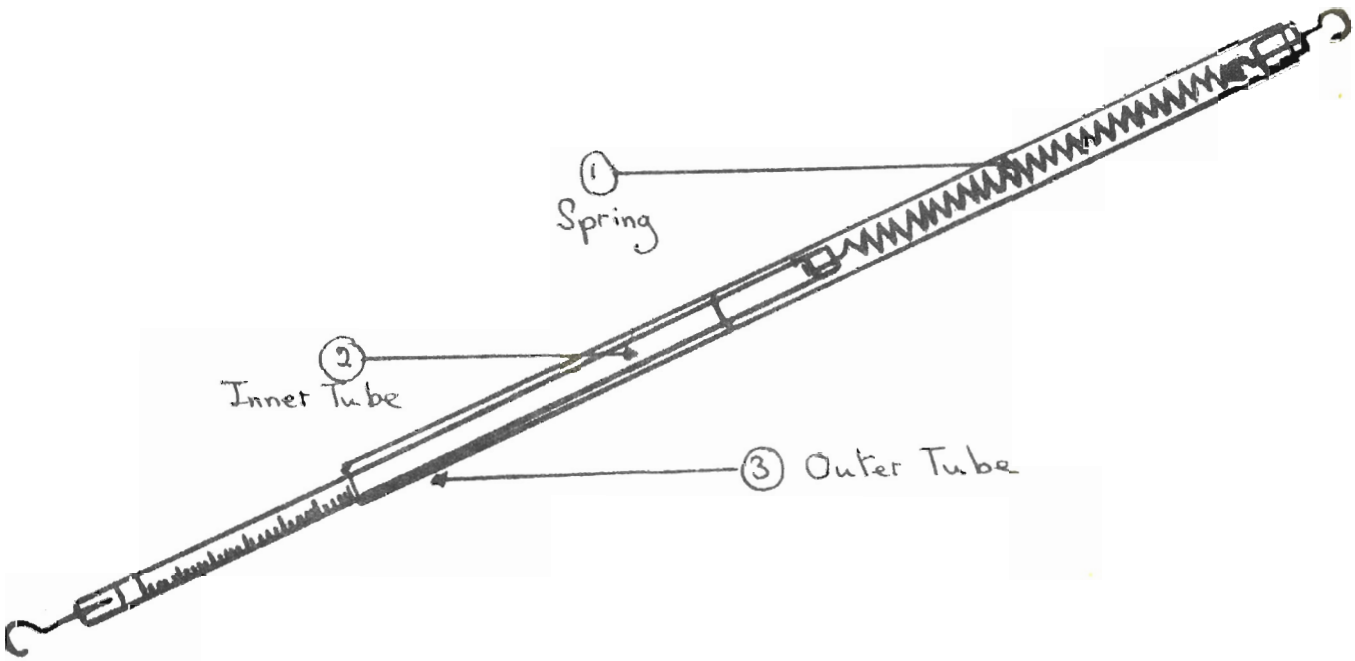
2.10/03 Rebound Apparatus



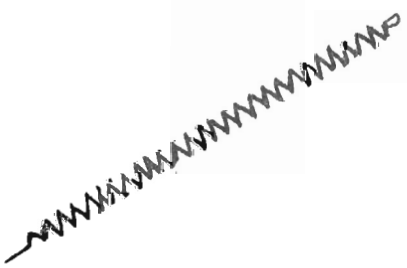
(1)	Steel Block	This will have to be obtained from a metal workshop. It is important that the end surface should be smooth and reasonably polished.
(2)	Lead Block	Heat some lead in a can, and when molten pour it into a sand mould.
(3)	Base	Cut the base from wood. Make an inset (say 0.4 cms) into the top surface to hold the blocks, and glue these firmly in position.
(4)	Suspended Spheres	Two spheres (1.2 cms diameter) are required, one of Lead and one of steel. Make the lead one as usual by pouring lead into a mould (cylindrical), and then filing it to an approximately spherical shape. Screw a cup screw into the sphere.

For the steel sphere take a ball bearing, and attach a cup screw by soldering. The two spheres should then be connected to one another by a length of string (50 cms).

2.10/04 Spring Balance



(1) Spring



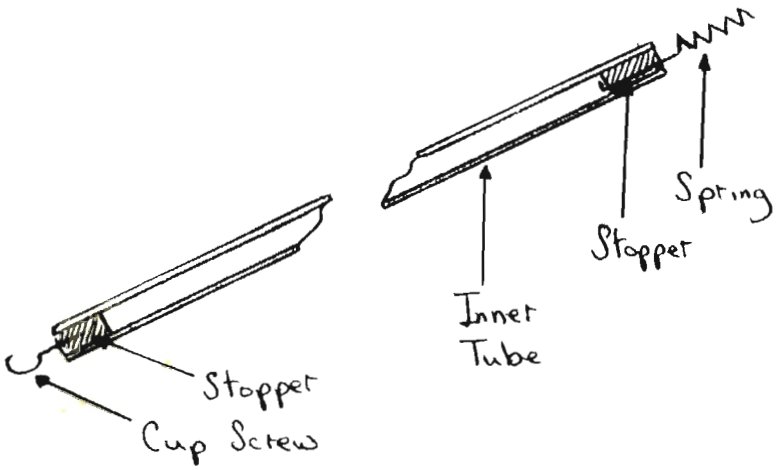
The method of winding the spring has already been described for the wire spring, making use of a brace (Item 2.10/02).

If a 10 Newton balance is to be made take #26 gauge steel wire (diameter 0.07 cms) and open wind it (0.1 cms between each turn) into a spring approximately 8 cms long and 0.9 cms in diameter.

If a 1 Newton balance is to be made take #30 gauge steel wire (diameter 0.03 cms) and open wind it (0.1 cms between each turn) into a spring approximately 8 cms long and 0.6 cms in diameter.

Make a loop on one end of the spring (using dog nosed pliers) and a straight piece on the other end.

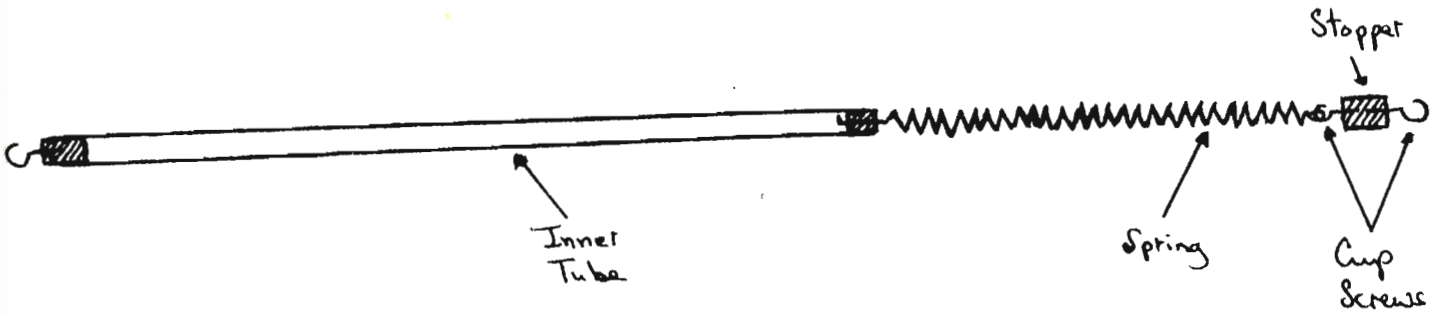
(2) Inner Tube



Take a hollow aluminum tube (length 21 cms, external diameter 1 cm), and make two stoppers out of wood (2 cms long, 1 cm diameter). Fix a cup screw into one of the stoppers and glue it permanently into one end of the aluminum tube. Drill a small central hole through the other stopper and insert the straight end of the spring, bending the end over to hold it in position. Glue the stopper into the other end of the tube.

(3) Outer Tube

Take a hollow aluminum tube (length 27 cms, internal diameter 1.3 cms) and make a wooden stopper (2 cms long, 1.3 cms diameter) to fit one end of the tube. Fix cup screws in either end of the stopper, and attach the top end of the spring to one of the cup screws.



Now, take the combination of stopper, spring and inner tube, and lower it into the outer tube until the stopper lodges in the top of the tube. Glue the stopper firmly into the tube.

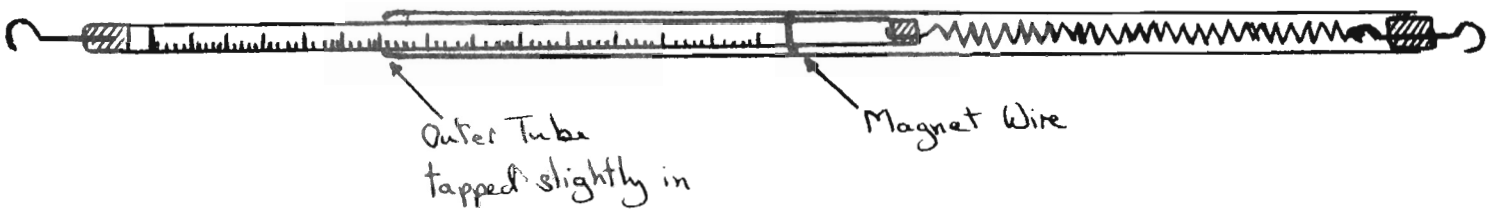
Notes:

(i) To calibrate the 10 Newton spring hold the balance vertically, and mark the inner tube opposite the lower end of the external tube (0 Newtons). Suspend 1,020 gms from the spring and once again mark the inner tube opposite the lower end of the external tube. Then subdivide the distance between the two marks into 100 equal divisions, thus permitting the balance to read from 0.0 to 10.0 Newtons with an accuracy of 0.1 Newtons.

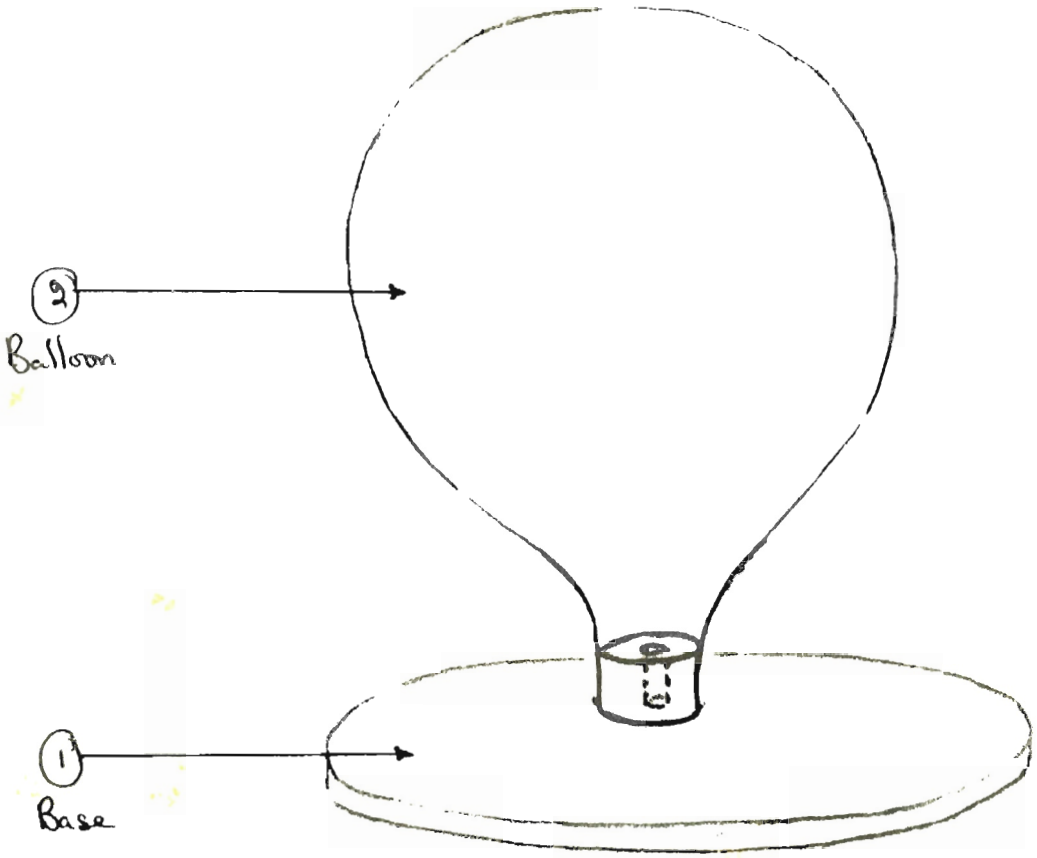
(ii) To calibrate the 1 Newton spring simply suspend a mass of 102 gms from the balance and repeat the above process, calibrating the inner tube from 0.00 to 1.00 Newtons with an accuracy of 0.01 Newtons.

(iii) Spring balances are very easily damaged by over extension of the spring. It is therefore useful to make some simple device to prevent over stressing the spring.

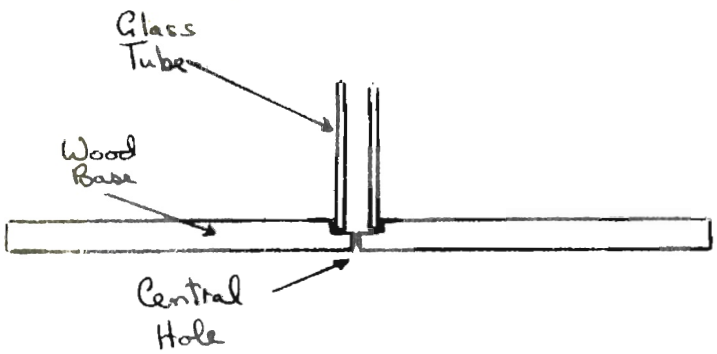
One such method is to tie a piece of magnet wire (diameter 0.05 cms) around the inner cylinder, just above the final marking on the scale. If the lower perimeter of the outer tube is then tapped gently all around it, the magnet wire will be unable to move beyond this point, thus preventing over extension of the spring.



2.10/05 Puck



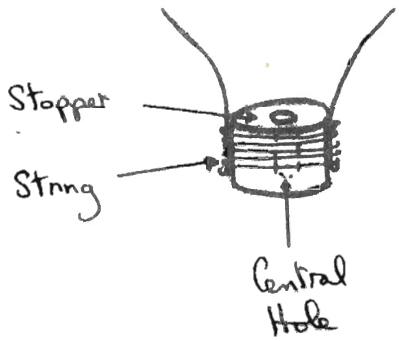
(1) Base



Cut the base out of wood (diameter 10 cms, thickness 0.7 cms). Polish and varnish the lower surface on successive occasions until it is perfectly smooth.

Drill a small hole (0.1 cms) through the center of the base, and drill an inset (0.3 cms deep, 0.5 cm diameter) over this to hold the glass tube (2.5 cms long, 0.5 cms external diameter). Seal the tube firmly in position with epoxy resin.

(2) Balloon

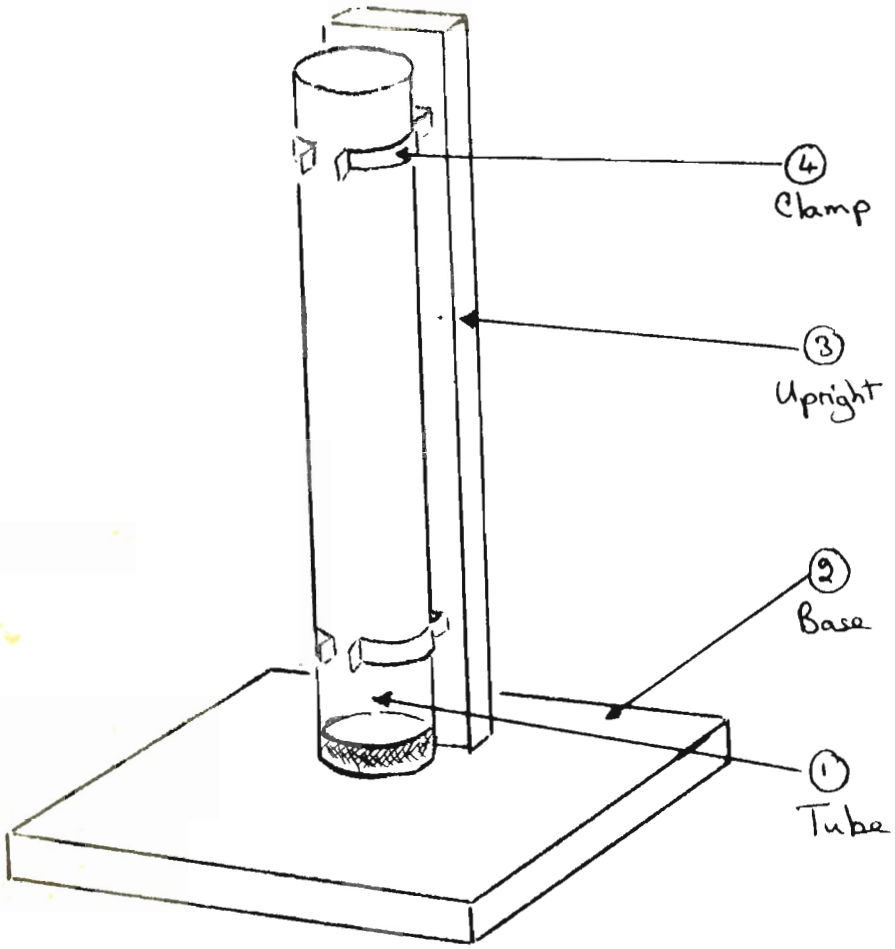


A suitable balloon would have a diameter of approximately 15 cms when inflated, and would be spherical in shape (not elongated). Insert a rubber stopper (2.5 cms long, 2 cms diameter) into the neck of the balloon after drilling a hole (0.5 cms diameter) through it to take the glass tube from the base. If necessary hold the balloon firmly in position on the stopper by wrapping string tightly around the neck.

Notes:

(i) To prepare the puck for use, hold the base in one hand with your finger over the small central hole. Take the balloon in your other hand and inflate it. Push the stopper of the balloon as far onto the glass tube as possible. The puck is ready for use on a smooth surface (e.g., table with glass cover, formica table top, etc.).

2.10/06 Friction Tube with Stand



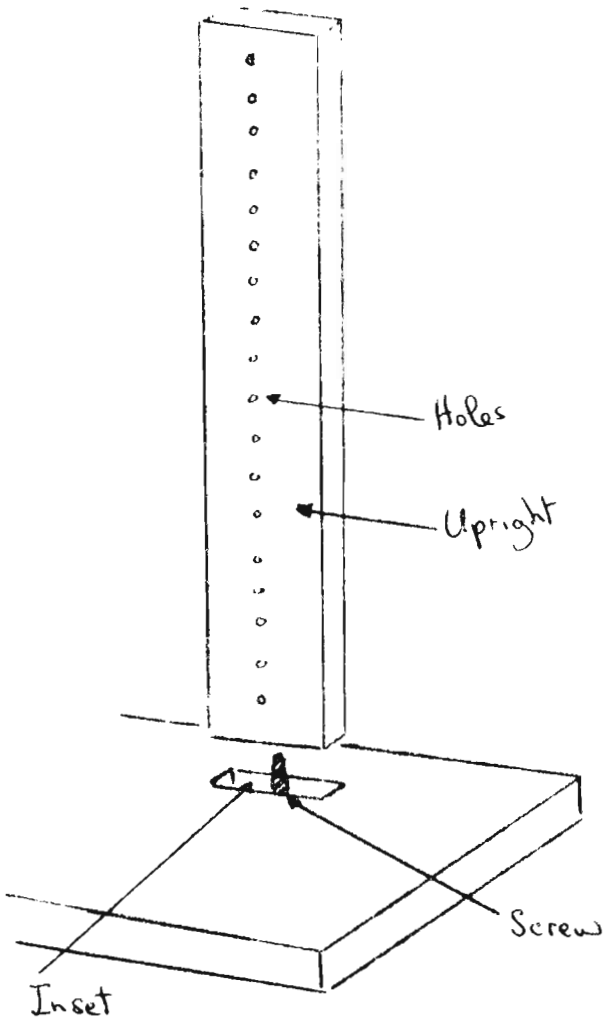
(1) Tube

Take a discarded fluorescent tube (approximately 100 cms long, 4 cm diameter), and wash off the internal white coating. You will find this is easily removed. Fit a cork into the bottom of the tube, and seal (watertight) it with rubber cement or ordinary paint.

(2) Base

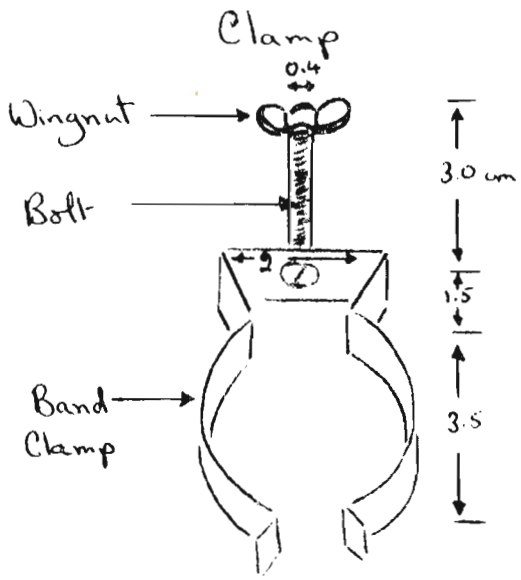
Cut the base out of wood (20 x 20 x 2 cms), and cut an inset (2 x 2 cms) about 1 cm deep into the base to support the wooden upright.

(3) Upright

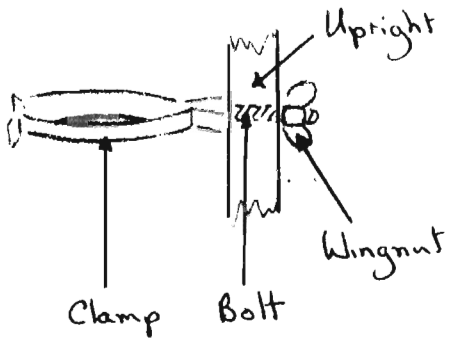


Put wood glue into the inset, and then attach the upright (100 x 2 x 2 cms) to the base with a screw from below. Bore horizontal holes (0.5 cm diameter) through the upright at regular 5 cm intervals.

(4) Clamp



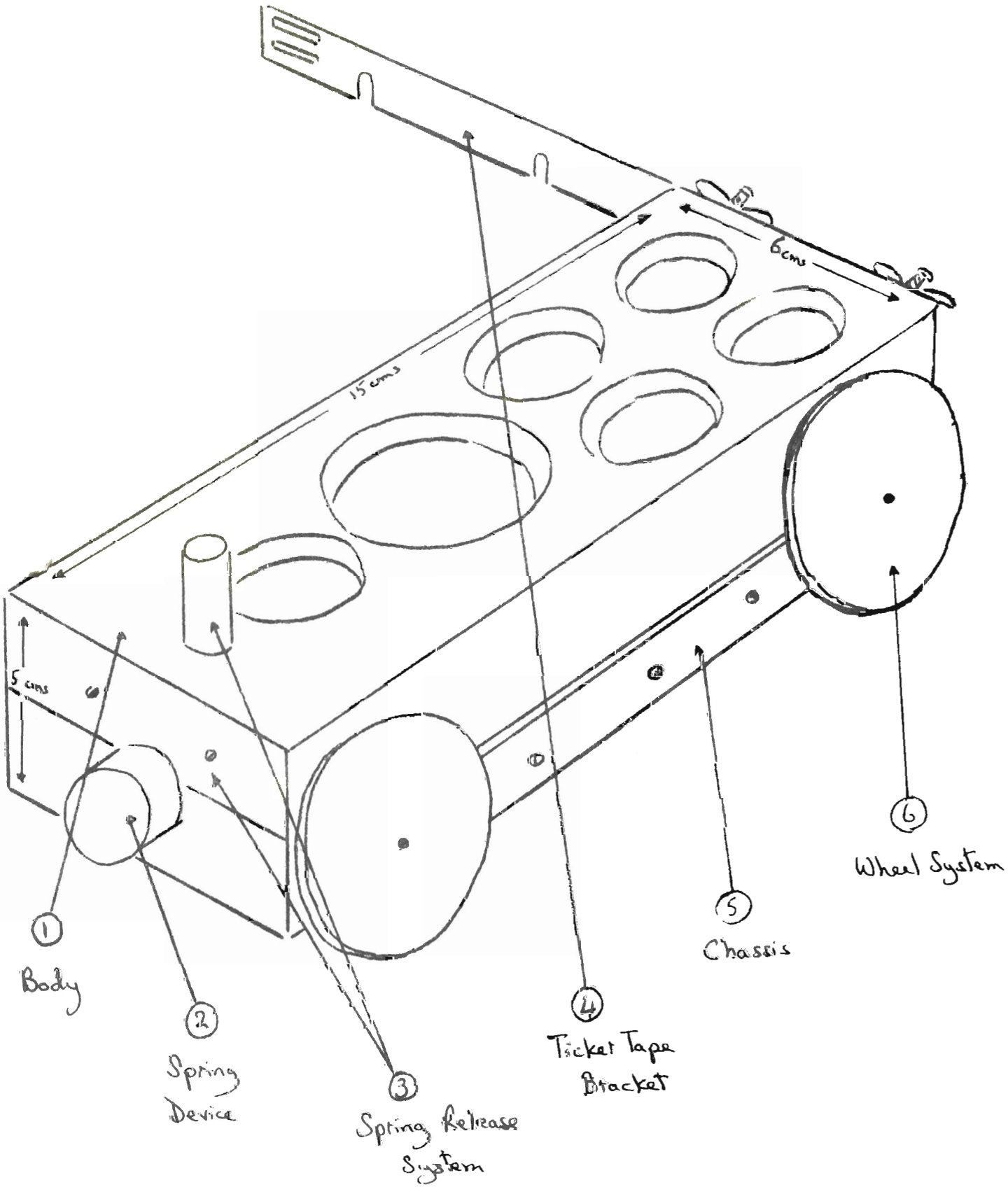
To make each of the clamps take a 14 cm length of steel strip (packing case bands about 1 cm wide will do), and bend into the shape shown. Drill a hole (0.4 cm diameter) in the center of the straight piece, and insert a bolt (3 cms long, 0.4 cm diameter) through it.



The clamp is attached to the upright by means of the bolt and an appropriate wingnut.

Notes: The stand is not an essential requirement for the friction tube for the tube could easily be handheld. However, the stand is included in the description since it is a useful general item.

2.10/01 Simple Cart



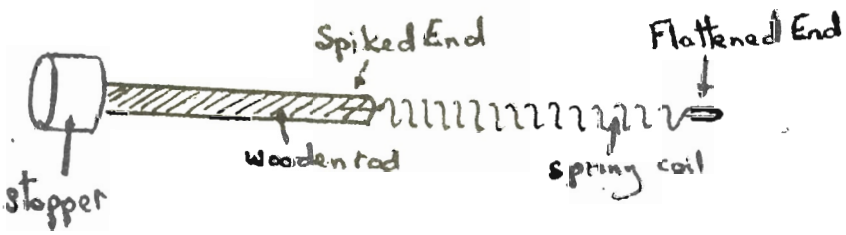
(1) Body

Cut the body (15 x 6 x 5 cms) from a piece of wood.

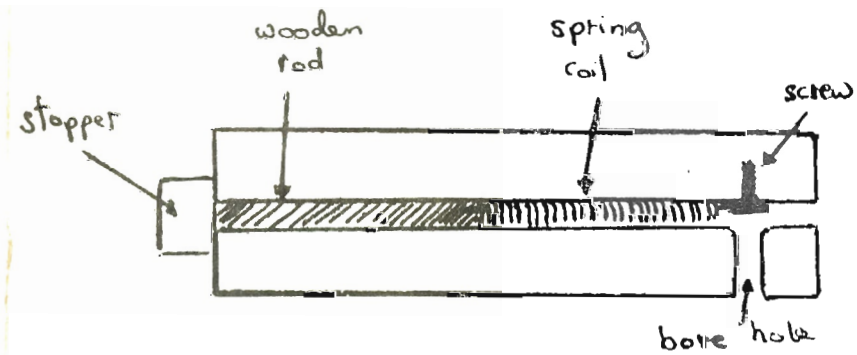
Bore a hole from the center of one end of the cart to the center of the other end, in order to accommodate a spring device. The diameter of the hole (1.2 cm) should be slightly larger than that of the spring (0.9 cms).

Bore holes into the top surface of the cart to accommodate six masses (see 1.20/02), namely one 100 gm mass (diameter 2.5 cms), four 200 gm masses (diameter 2.5 cms) and one 500 gm mass (diameter 4.0 cms). The holes should not be so deep as to cut into the horizontal hole for the spring.

(2) Spring Device



Wind some 40 cms of steel wire (#26, diameter 0.07 cms) into an open spring (separation of each turn about 0.4 cms) approximately 8.5 cms long and 0.9 cms diameter (see details under 2.10/02 and 2.10/04). Straighten out one end of the spring into a spike and the other to a horizontal loop.

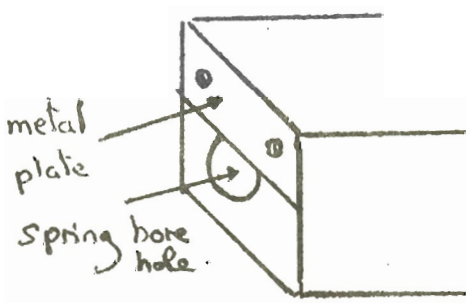


Cut a wooden rod (10 cms long, 0.9 cms diameter), and attach the spring to one end by means of the spike and epoxy resin. Attach a rubber stopper (approximate diameter 2.5 cms, length 1.5 cms) to the other end of the rod.

Bore a hole into the bottom of the cart so that it meets the bore hole for the spring close to the rear end of the cart. Then insert a screw to anchor the end of the spring.

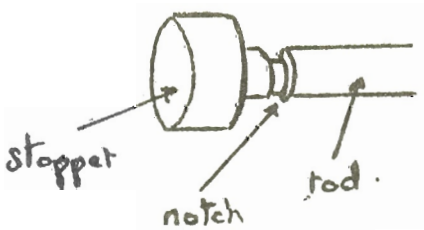
Ideally, two or three alternative springs of varying thickness and length should be made for trial purposes. The ultimate spring selected will be such that if two identical carts (one carrying 3 times its own weight) are placed end to end, and the spring device on one cart is then released, both carts will move apart a sufficient distance at uniform velocity to enable a measure of their initial separation velocities to be recorded.

(3) Spring Release System



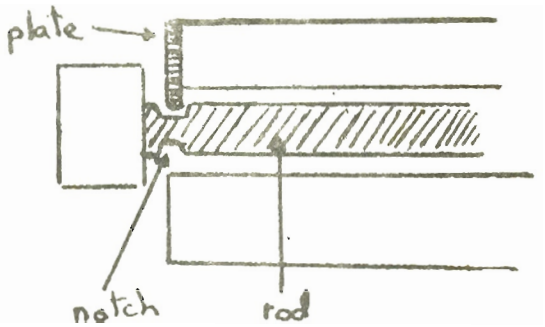
Screw a metal plate (brass, steel, etc.) onto the front of the cart so as to just overlap the top of the borehole for the spring.

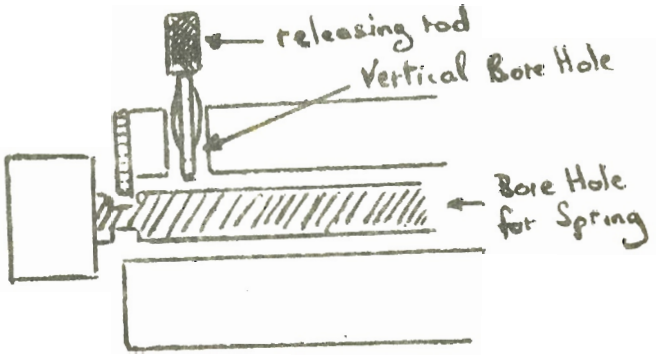
File a small notch around the wooden rod on the spring device, close to the stopper.

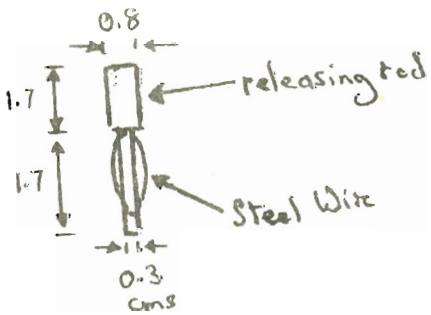


It is thus possible to compress the spring into the bore hole, and hold it in position by means of the notch and metal plate.

Bore a vertical hole (diameter 0.5 cms) into the top of the cart, near the front end, so that it meets the



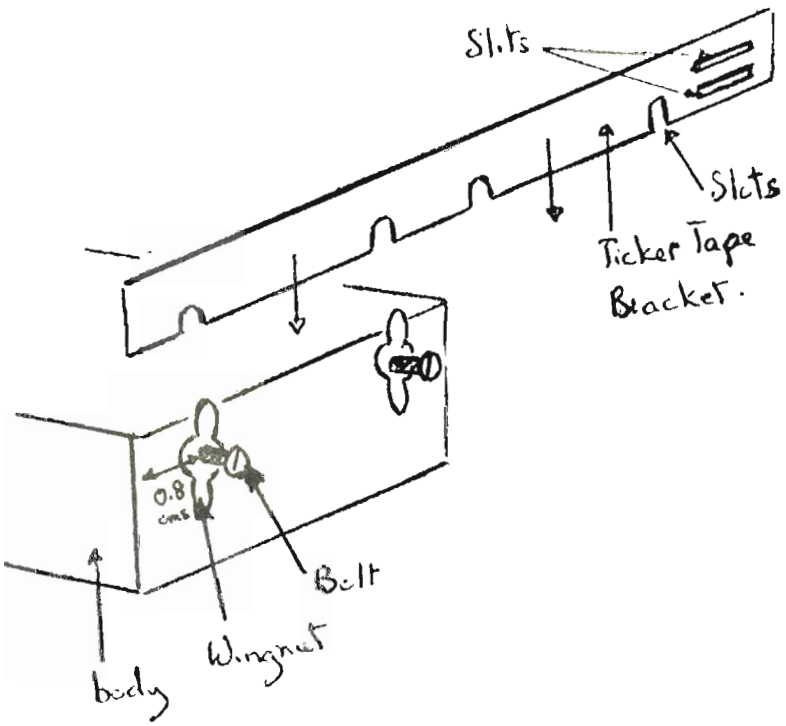




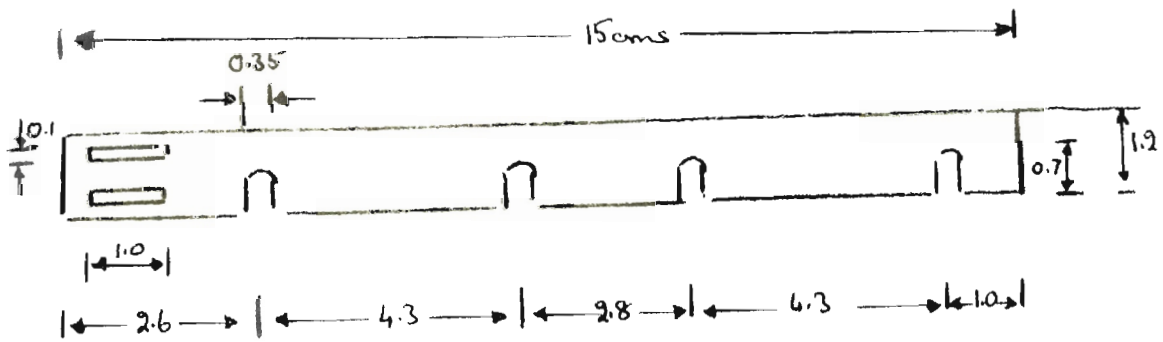
horizontal bore hole for the spring. A small wooden rod (releasing rod) inserted into this hole, and pressed against the horizontal rod of the spring device itself, will release the spring from its state of compression.(The need to have the diameter of the spring bore hole slightly greater than that of the spring and attached rod should now be clear, for it is an essential requirement if the spring is to be released).

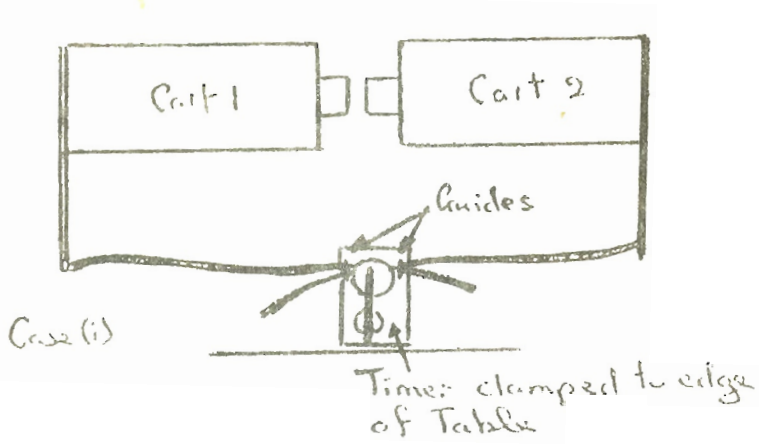
Cut the releasing rod to the dimensions illustrated. The rod should be capable of moving freely in its bore hole, but at the same time it shouldn't be so loose that it is easily lost. To realize this condition thread a thin piece of steel wire (#30) through the rod so that it acts as a spring contact between the sides of the rod and the bore hole.

(4) Ticker Tape Bracket

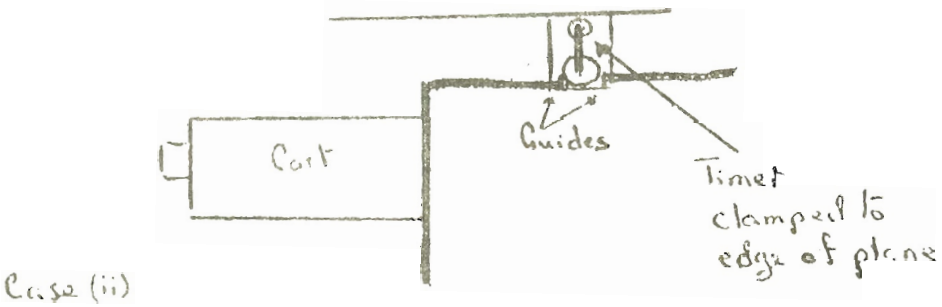


Cut the ticker tape bracket from a sheet of metal (brass, aluminum) which should be reasonably rigid. Make slits near the end to take the ticker tape, and slots along the bottom to enable the bracket to be attached to bolts (0.3 cms diameter) at the rear of the cart. Wingnuts should be used to fasten the bracket in position.

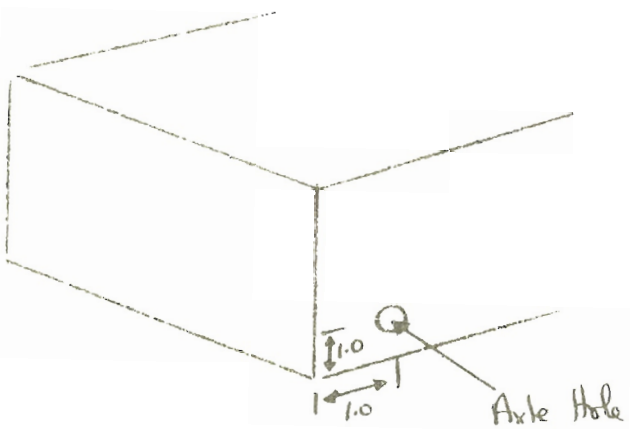




The purpose of the bracket is to insure that ticker tape attached to the cart is in line with the guides of the timer during any experiment, thus reducing friction. Two typical examples are illustrated when carts are mutually repulsed from one another (Case i), and when a single cart runs down an inclined plane (Case ii).

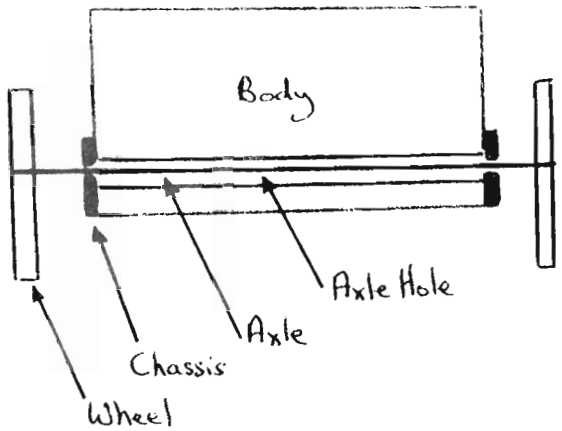


(5) Chassis



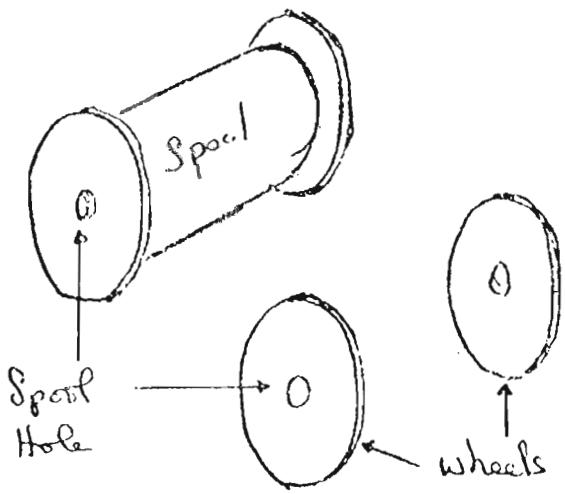
Drill two horizontal holes (0.5 cms diameter) through the cart to permit passage of the front and rear axles.

Cut the chassis from metal (steel, packing case bands, 15 x 1.5 cms). Drill 5 holes along the length of the strip, 2 (diameter 0.3 cms) to coincide with the centers of the axle holes and 3 to enable the strip to be attached firmly to the body with screws.

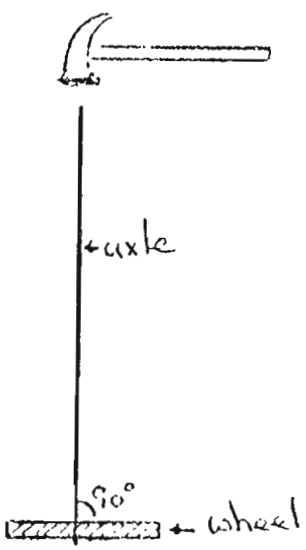


The axles of the cart will in fact pivot in the chassis holes and not on the wooden holes through the cart, thus reducing friction.

(6) Wheel System

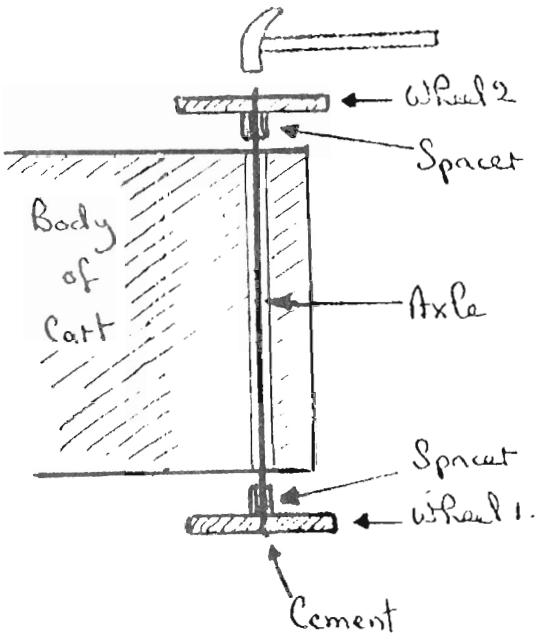


Cut the four wheels from the ends of two wooden spools (approximately 4 cm in diameter and 1 cm thick). Fill the spool holes (0.5 cm diameter) with wood putty and allow to dry hard.



Cut two lengths of wire (approximately 0.2 cm diameter, 10 cms long) from wire coathangers to serve as axles for the cart.

Drill holes, slightly less than 2 mm in diameter, in the exact center of each wheel, and insert a little epoxy resin in the holes.



Tap the end of one axle into one of these holes, checking carefully to insure that the axle is at right angles to the wheel (thus avoiding subsequent wheel wobble).

Insert the axle through the body of the cart, and attach a second wheel by the same process. Repeat the procedure with the remaining two wheels and axle, thus providing the cart with front and rear wheels.

Make small spacers for all four wheels from masking tape (1 cm wide), in each case wrapping it around the axle (next to the wheel) until it produces a cylindrical spacer 1 cm long and 0.5 cm in diameter.

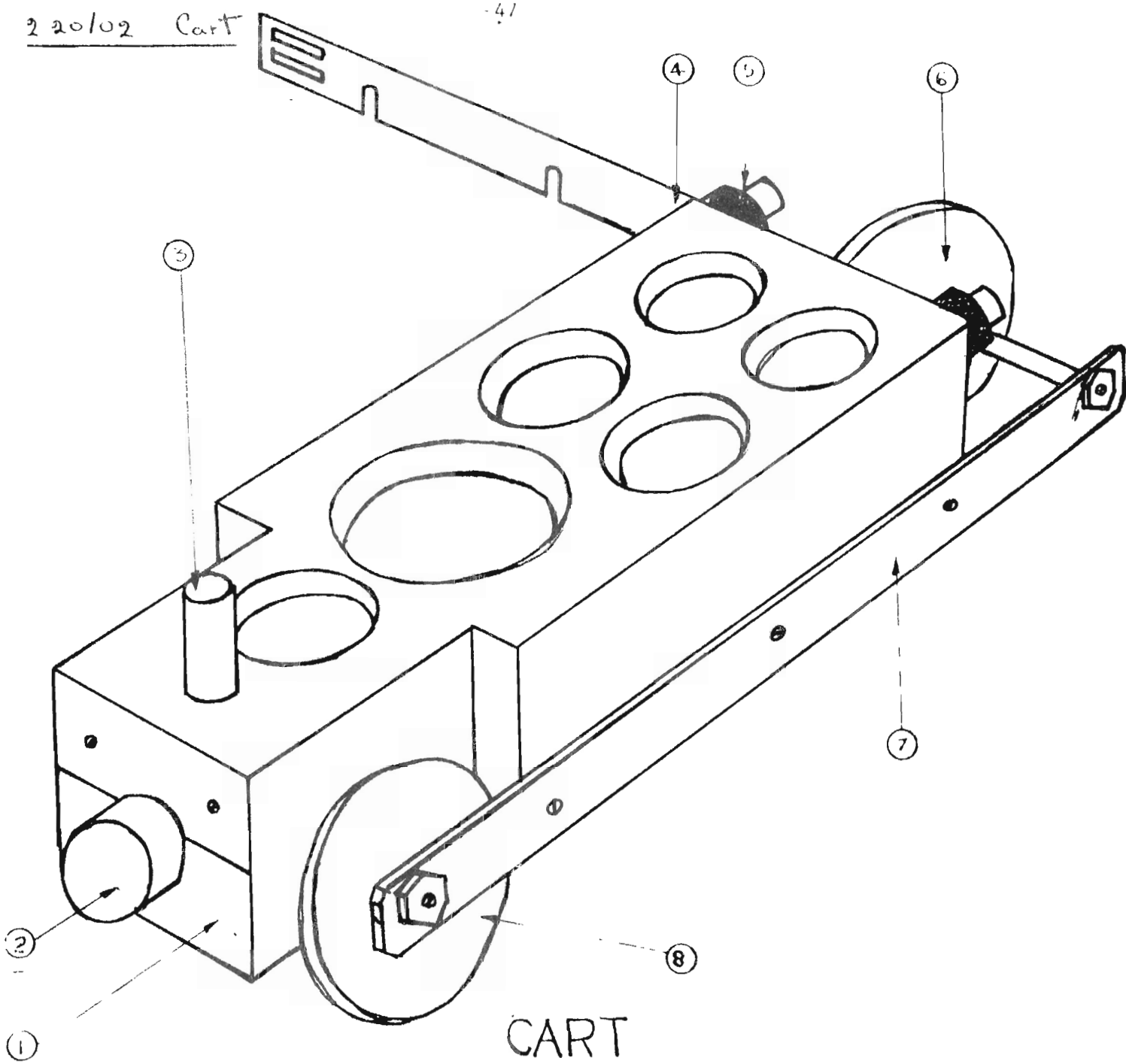
A little soap applied to each axle will serve as a lubricant between the axle and chassis contact points.

Notes:

(i) Adjust the total weight of the cart to 400 gms by cutting some wood off the under surface of the body, and drill the holes in the top surface somewhat deeper if necessary.

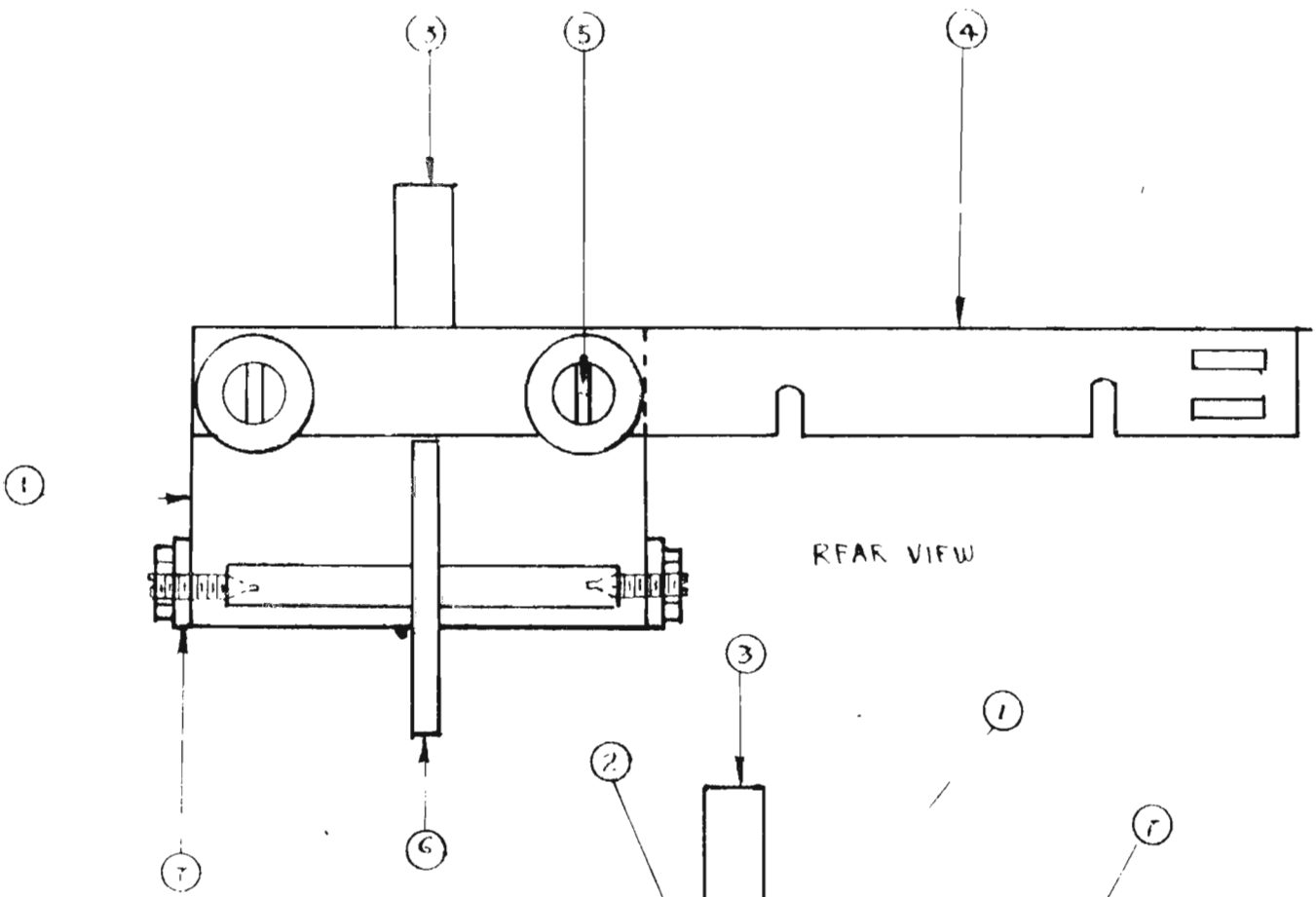
(ii) A superior wheel system can be made if a metal lathe and a reasonably skilled technician are available. With this in mind a technical drawing of an almost identical cart, with a modified wheel system, is included next.

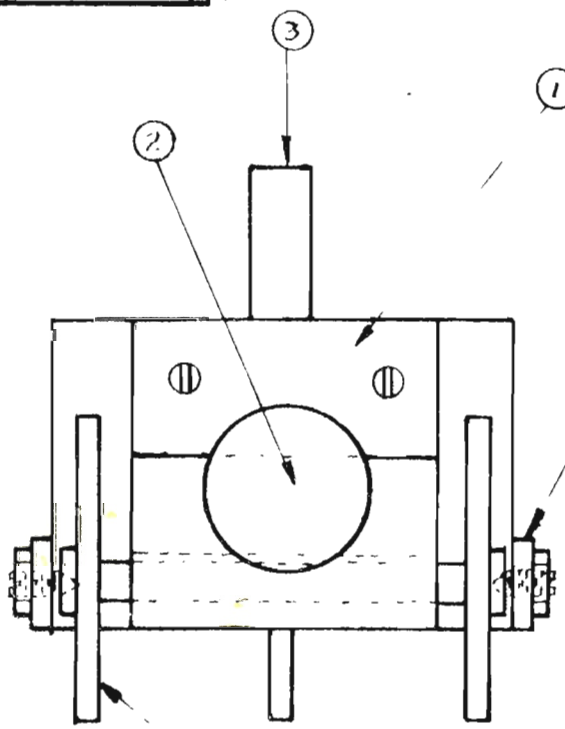
2 20/02 Cart

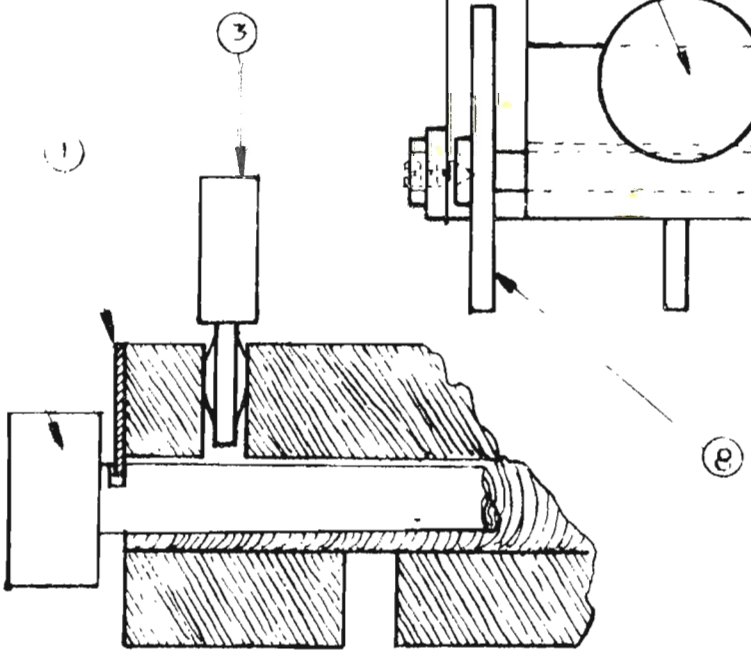


CART

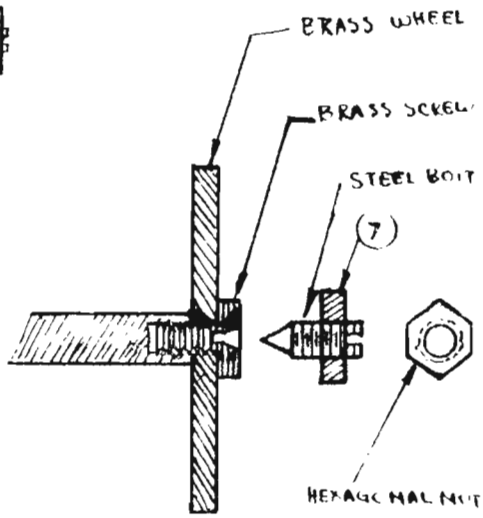
PART NO.	DESCRIPTION	DIMENSIONS	QUANTITY
1	BODY - (NARRA) WOOD	4.0X6.0X15.0	1
2	SPRING W/ RUBBER STOPPER	0.4 X2.0	1
3	SPRING RELEASE - NARRA WOOD & WIRE SPRING	Ø 0.8X4.0	1
4	TICKER TAPE HOLDER - ALUMINIUM	0.15X1.2X15.0	1
5	TICKER TAPE HOLDER SCREWS - BRASS	1.0X2.0	2
6	REAR WHEEL & AXLE - BRASS & STEEL	0.8X4.0	1
7	CHASSIS - STEEL	0.8X1.2X16.3	2
8	FRONT WHEEL & AXLE - BRASS & STEEL	0.8X4.0	1





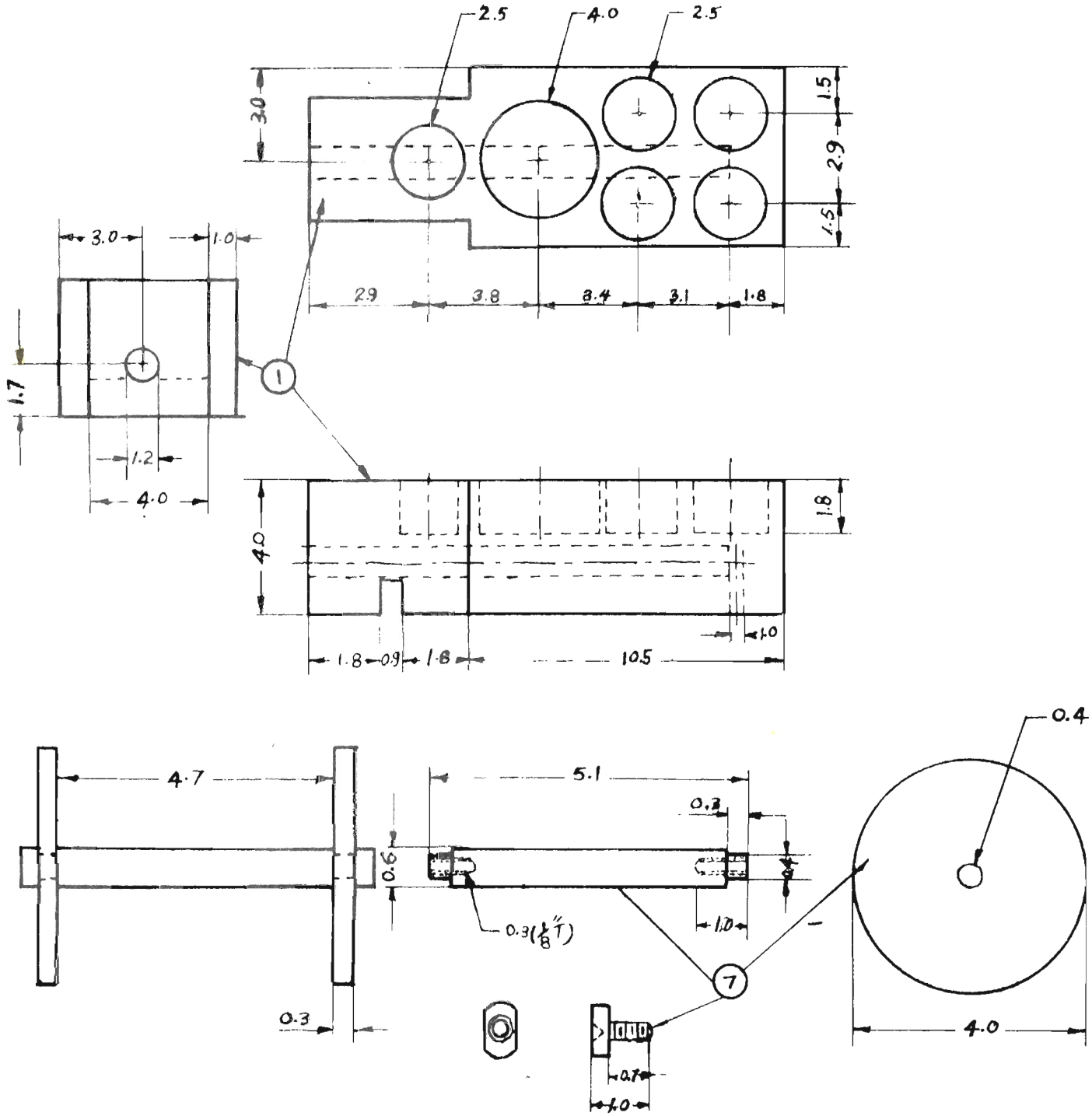


SPRING W/ STOPPER & SPRING RELEASE
CROSS SECTION

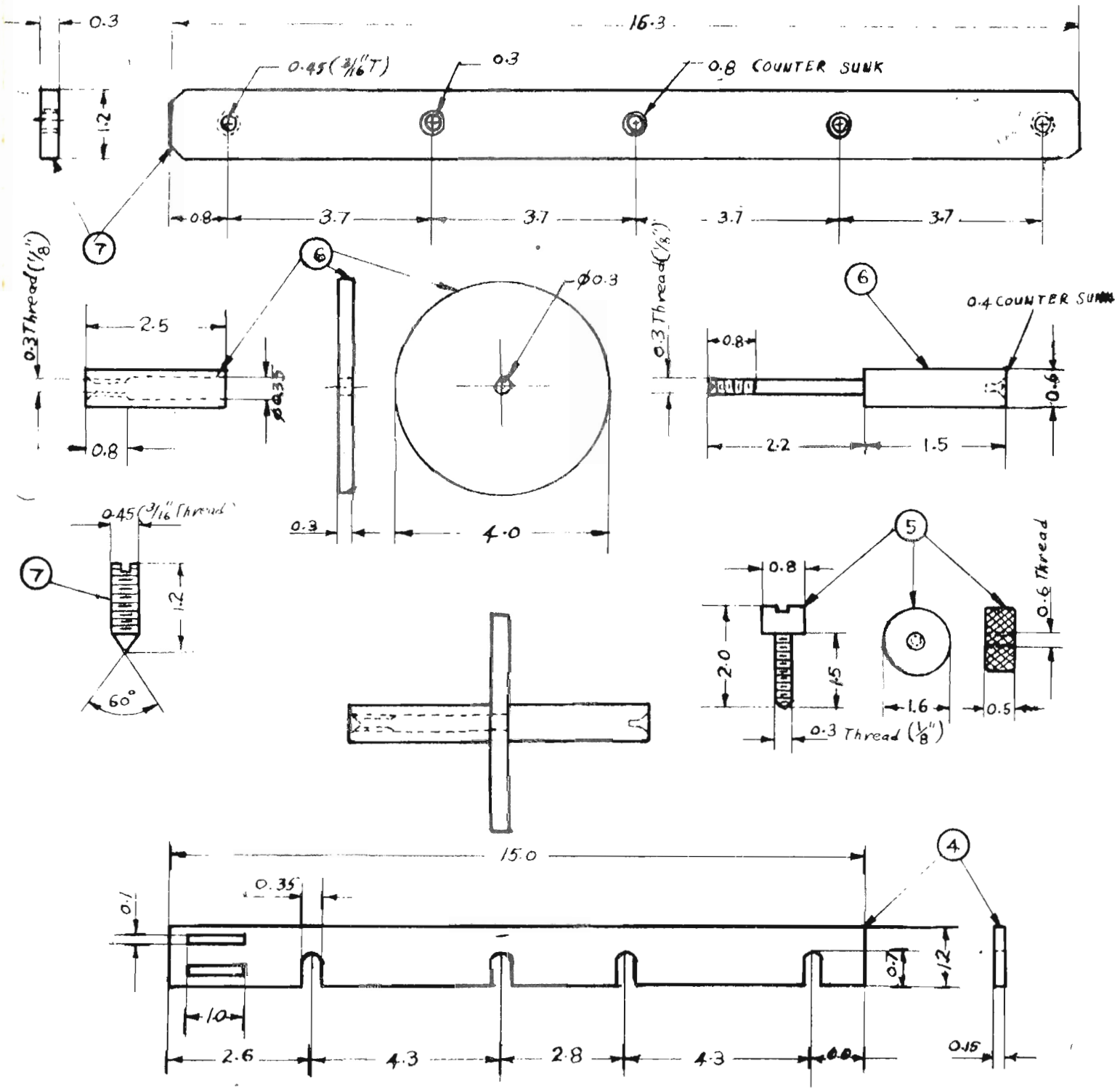


REAR WHEEL AND AXLE
CROSS SECTION

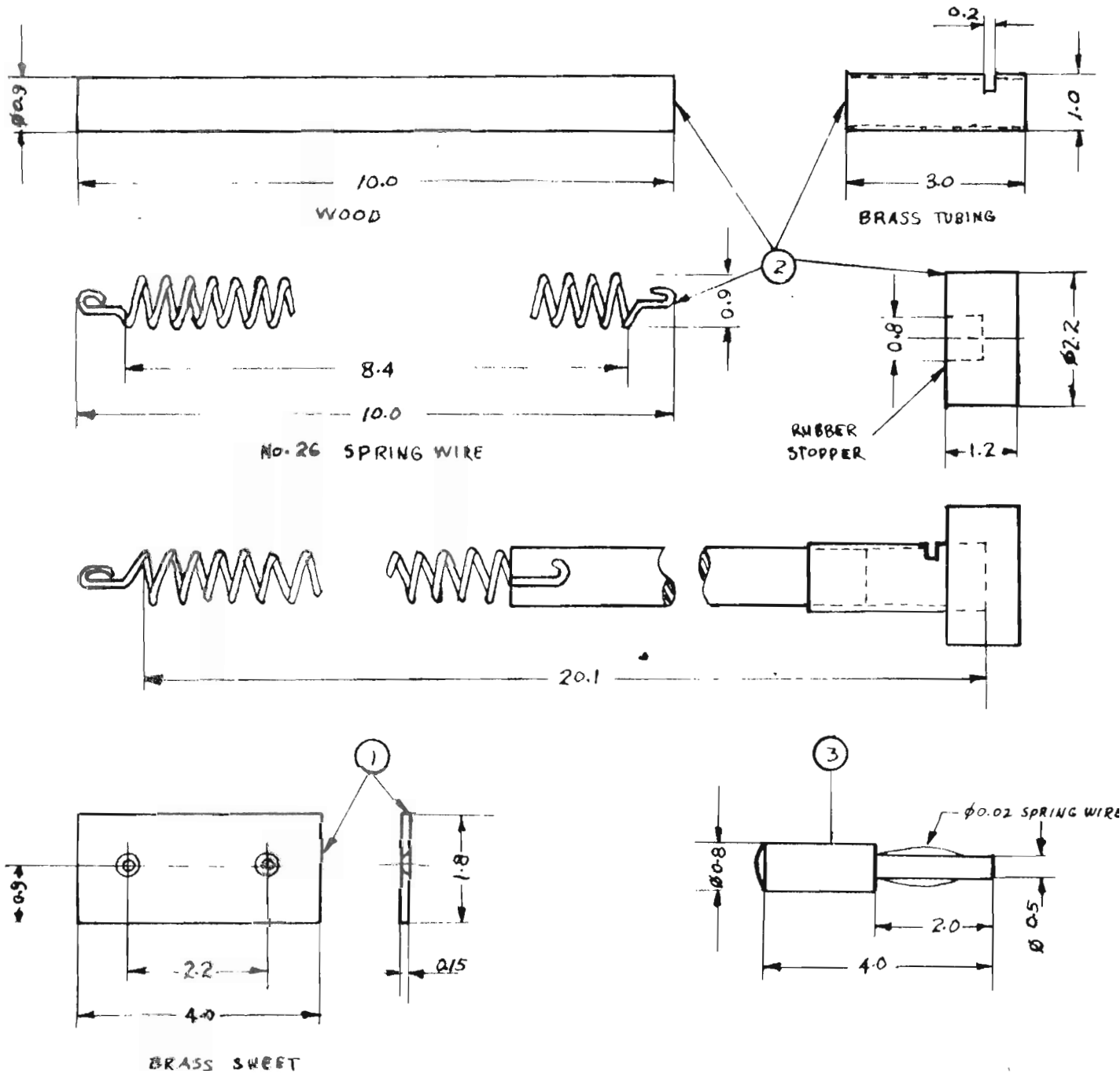
SCALE 1:1



PART NO.	CART PARTS 1-7	SCALE
1	(NARRA) WOOD BODY	2:1
7	2 BRASS WHEELS and 2 BRASS SCREWS	1:1
7	1 STEEL AXLE	1:1

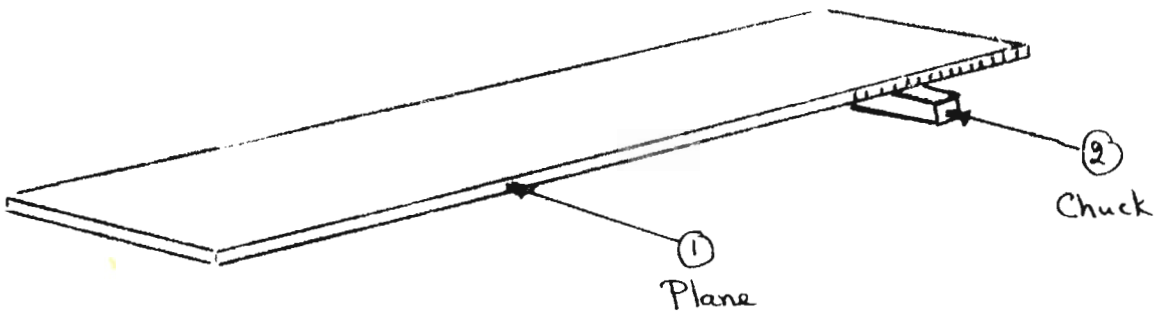


PART NO	CART PARTS 4-5-6-7	SCALE
4	1 TICKER TAPE HOLDER - ALUMINIUM	1:1
5	2 BRASS SCREWS and 2 BRASS NUTS W/ KNURLING	1:1
6	1 BRASS WHEEL and 1 REAR STEEL AXLE	1:1
7	2 STEEL CHASSIS	1:1
7	4 AXLES SCREWS and 4 HEXAGONAL NUTS	1:1



PART NO.	CART PARTS 1-2-3	SCALE
1	1 FRONT BRASS PLATE OF BODY	1:1
2	1 SPRING W/ RUBBER STOPPER	1:1
3	1 SPRING RELEASE W/ SPRING WIRE ϕ0.02	1:1

2.20/03 Inclined Plane



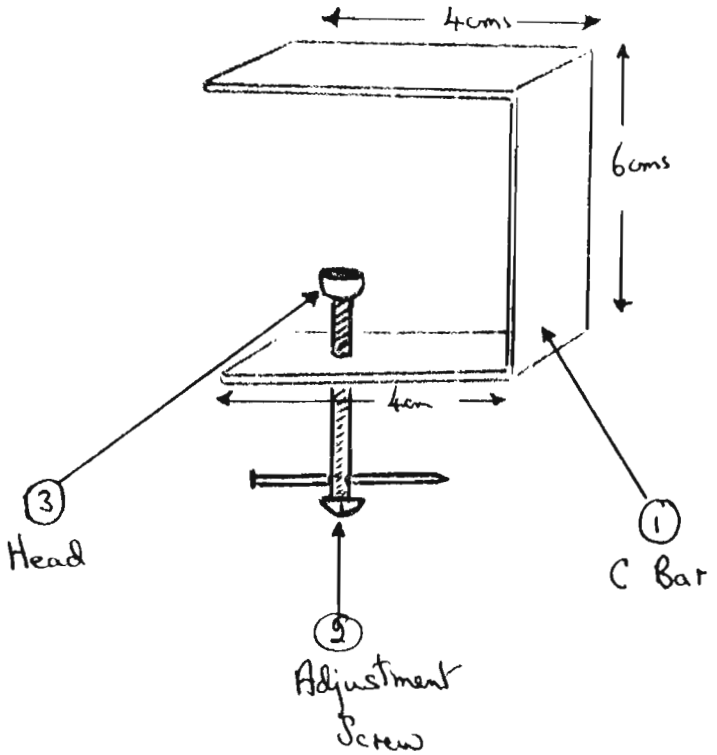
(1) Plane

Cut the plane from 5-plywood (150 x 18 x 2 cms) if possible, since this does not warp so readily. Two metal strips may be placed along the sides of the plane to prevent subsequent distortion. Mark a 15 cm scale along the top edge of the plane to check the chuck position, and hence indicate the inclination of the plane.

(2) Chuck

Make 4 wood chucks, each 18 cms long and 3 cms wide, with depths of 0.5, 1, 2 and 5 cms respectively.

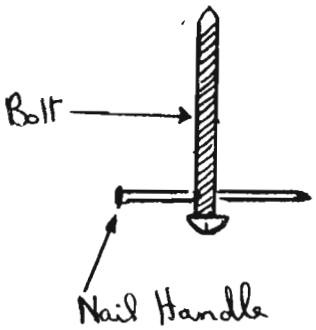
2.20/04 C Clamp



(1) C Bar

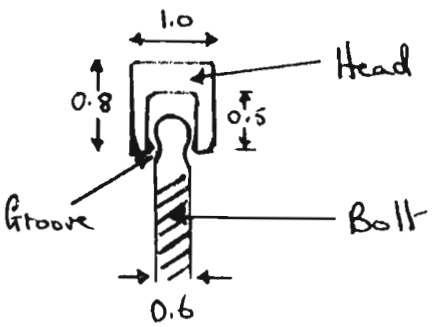
With the assistance of a heavy duty clamp, hammer an iron strip (14 x 2 x 0.3 cms) into the shape shown. If necessary apply heat to assist in the bending process. Drill a hole (0.6 cms diameter) through the center of one of the end pieces, and make a thread on it for the adjustment screw.

(2) Adjustment Screw



Obtain a heavy bolt (4 to 6 cms long, diameter 0.6 cms). Drill a hole (approximately 0.2 cms diameter) through it close to the flat end. Insert a nail (0.2 cms diameter, length 5 cms) through the hole to serve as the adjustment screw handle.

(3) Head

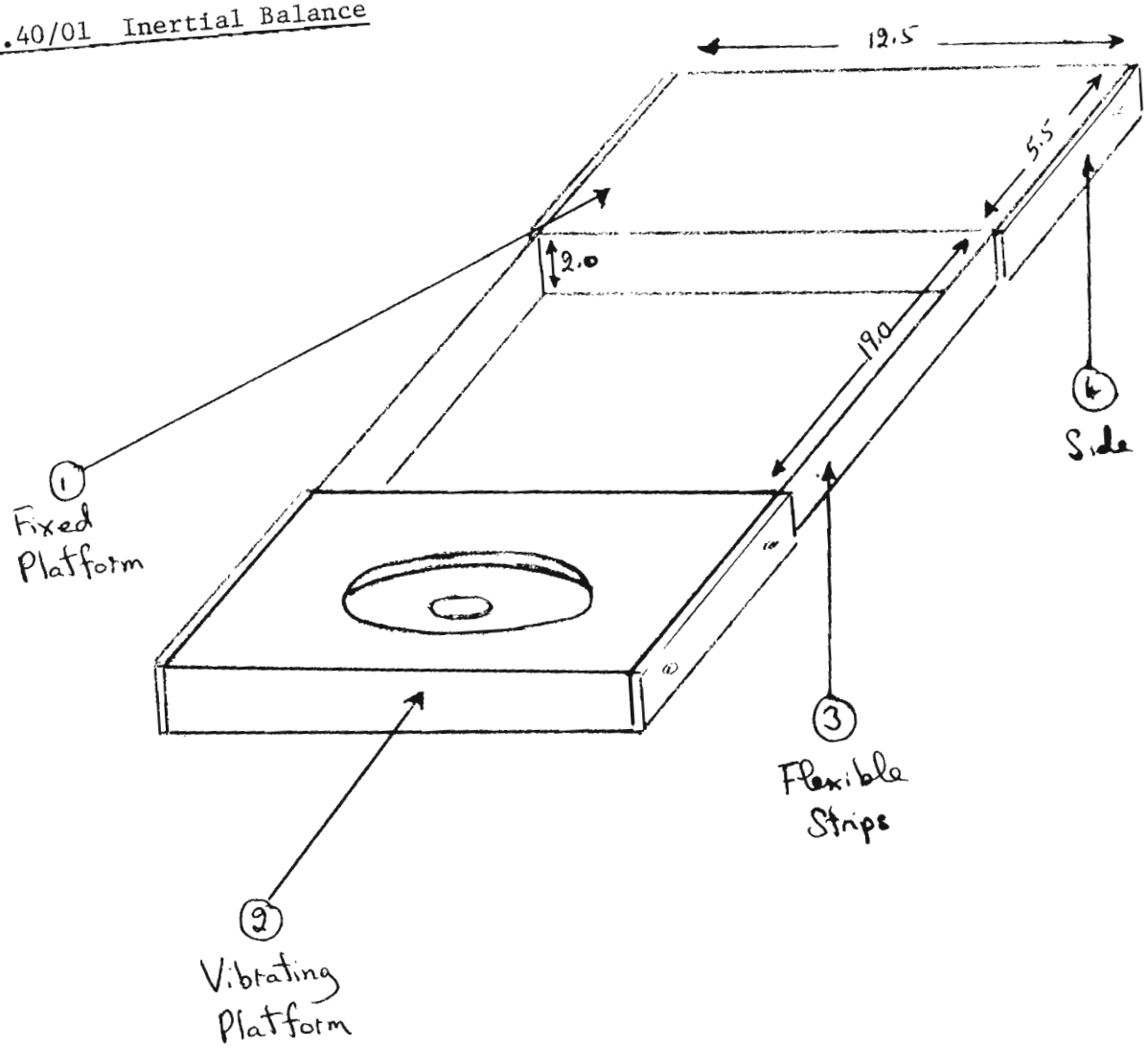


The clamp will work well without a head, but the pointed end of the bolt is likely to damage any surface to which the clamp is attached.

Take a soft iron rod (1 cm diameter) and cut off a length of 0.8 cms using a hacksaw. Drill a hole (diameter 0.6 cms) along its axis to a depth of 0.5 cms.

Take the bolt, and file a groove around it at about 0.4 cms from the pointed end, making the end spherical in shape. Push the shaped end of the bolt into the head, and tap the perimeter of the head lightly with a hammer so that it closes loosely over the shaped end of the bolt.

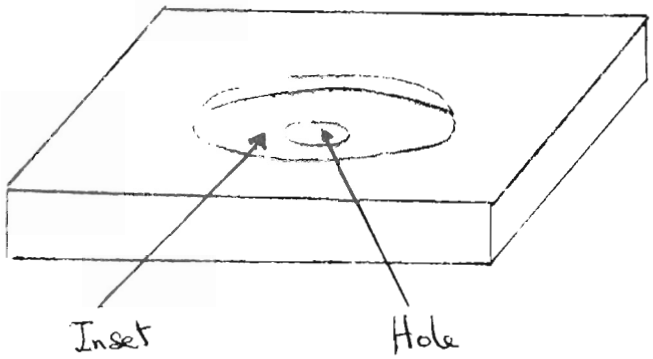
2.40/01 Inertial Balance



(1) Fixed Platform

Cut a simple platform (12.5 x 5.5 x 2.0 cms) out of wood.

(2) Vibrating Platform



Cut a second platform out of wood, identical to the first. In the center of the top surface of the platform make an inset (0.3 cms deep, 5 cms diameter) using a chisel. Then bore a hole (1.5 cms diameter) at the center of the inset right through the platform.

(3) Flexible Strips

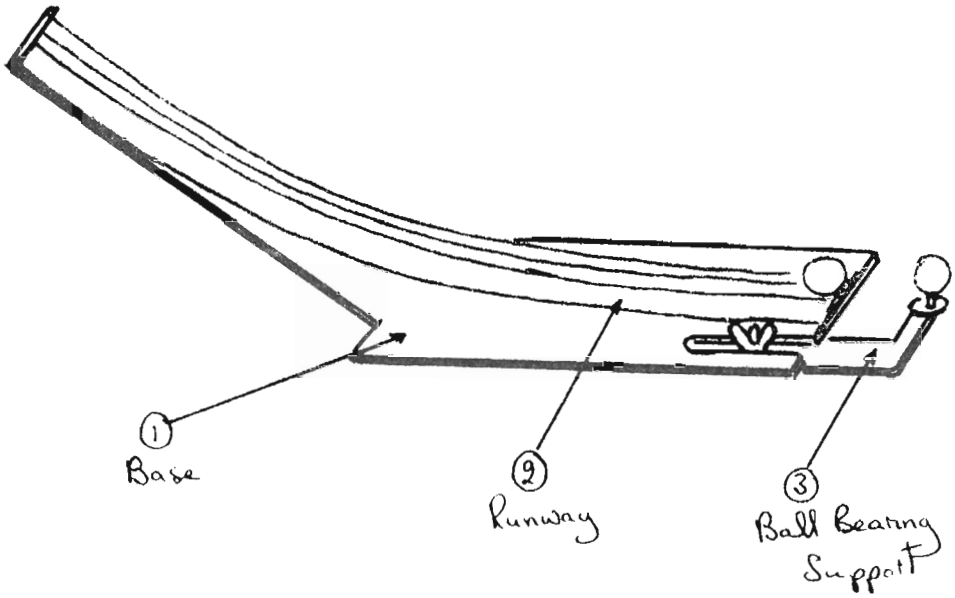
Drill suitable holes in the ends of two steel strips (each 30 x 1.2 x 0.05 cms approximately) and attach to the platforms as indicated. Each strip could be made from a double strip (not single) of packing case band material.

(4) Side Plates

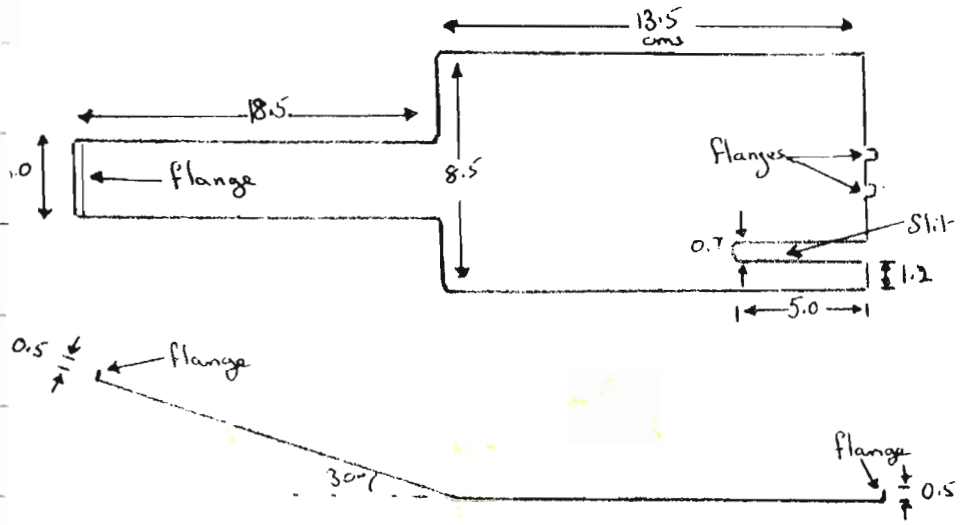
Cut 4 steel plates (5.5 x 1.2 x 0.2 cms). Drill a hole in each about 1 cm from either end, and screw on to the sides of the platform. The side plates prevent sideways motion of the flexible strips where they are in contact with the sides of the platform.

Notes: Adjust the weight of the vibrating platform and its 2 side plates to 100 gms, by cutting the inset deeper if necessary.

2.50/01 Elastic Collision Runway



(1) Base

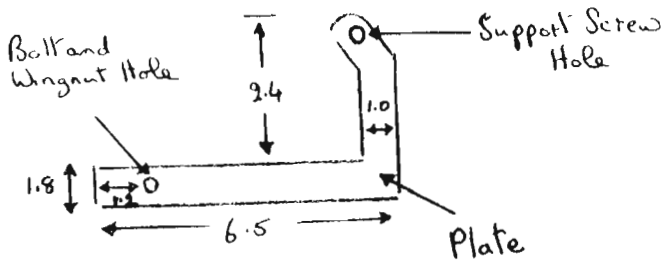


Cut the base from an aluminum sheet about 0.15 cms thick, which is reasonably rigid, but can still be bent. A slit is required to take the ball bearing support and flanges to hold the runway in position. Bend the base as shown at an angle of 30°.

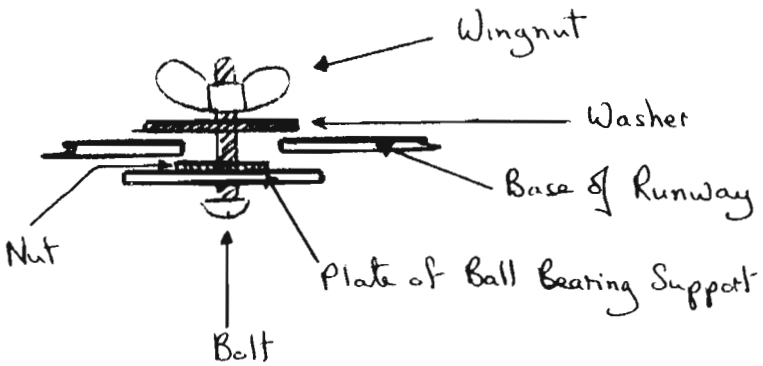
(2) Runway

The runway is simply a plastic ruler, 30 cms long with a typical groove down its center. Bend the base so that the runway is held firmly in position by the base flanges at either end.

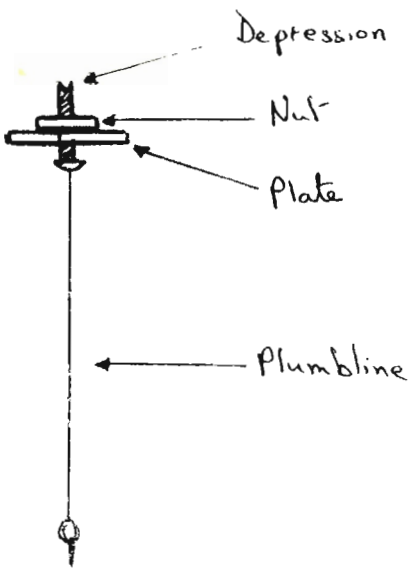
(3) Ball Bearing Support



Cut the plate from aluminum (0.2 cms thick) which is thick enough to be threaded. Drill two holes (0.4 cms diameter) as shown, and cut a thread (0.45 cm) so that the holes will take 0.45 bolts.

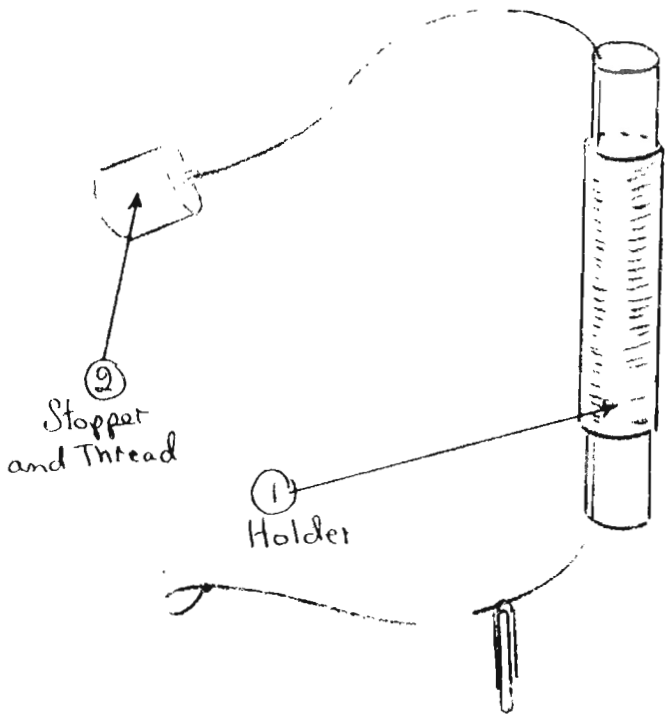


The plate is attached to the base by means of a bolt (1.5 cms long, 0.45 cms diameter), a nut, a washer (1.2 cms diameter) and a wingnut. The head of the bolt is flattened somewhat by filing so that it does not create two big a protrusion beneath the base.



The support screw is made from a bolt (2.0 cms long and 0.45 cms diameter). File the pointed end of the bolt flat, and then drill a depression into the surface to act as a support for ball bearings. Thread the bolt into the plate, and hold it firm by means of a nut. Finally tie a meter thread to the head of the bolt, and suspend a screw from it, so that it will serve as a plumbline.

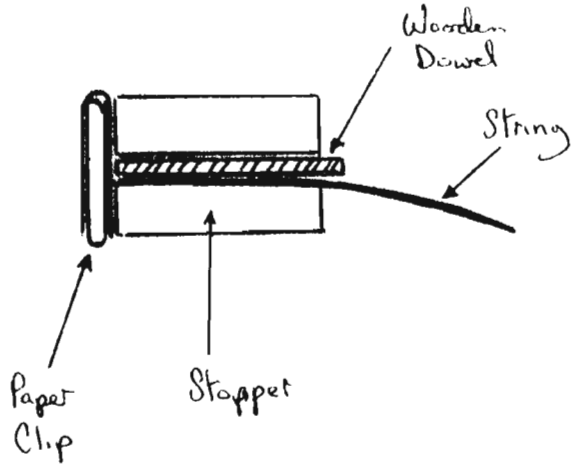
2.60/01 Centripetal Force Apparatus



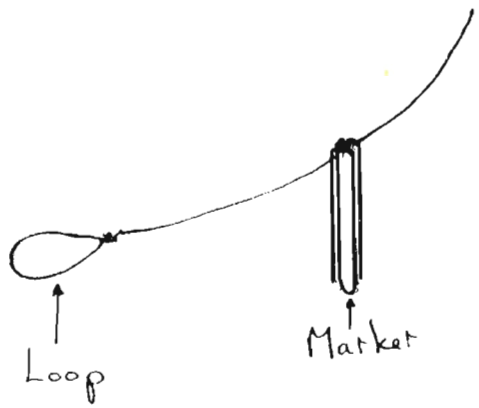
(1) Holder

Take a glass tube with an internal diameter of about 0.6 cms, and cut off a length about 13 cms long. (Simply file a sharp line around the tube and snap it with your hands). It is convenient to cover the glass tube with a length of rubber tube (bunsen burner tubing) which permits a better hand grip on the tube. Put the ends of the tube in a hot flame to smooth off the edges. This will prevent the cutting of the string as the stopper is whirled around.

(2) Stopper and Thread

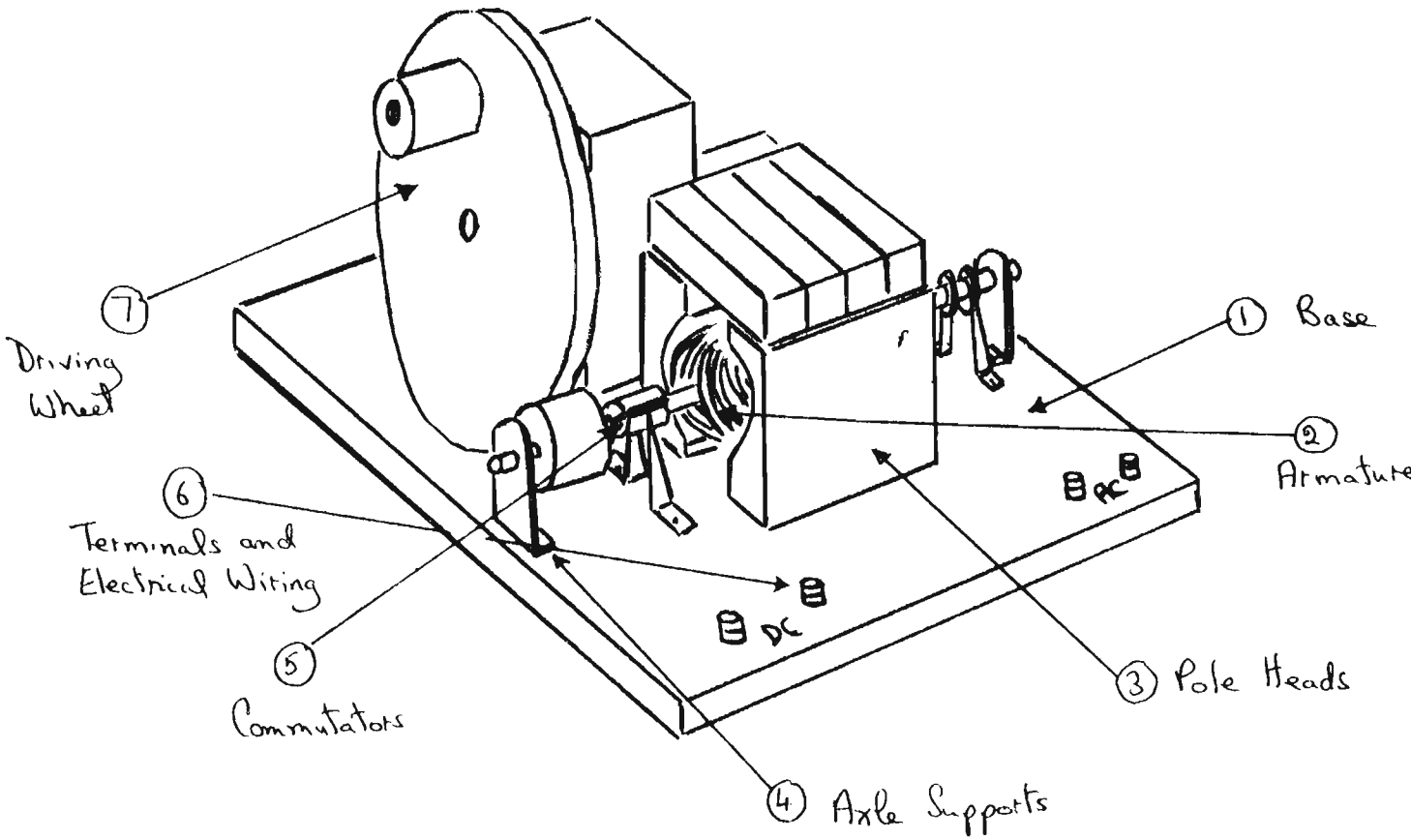


Take a rubber stopper (approximately 2.5 cms long, 2.5 cms diameter) and drill a hole (0.4 cms) along its axis. Fasten one end of a strong length of string (1 meter long) firmly to a paper clip, and thread the string through the hole in the stopper. Plug the hole with a wooden dowel (2.5 cms long, 0.5 cms diameter) so that the string is held firmly in position.



Thread the string through the holder, and tie a loop at the extreme end (to hold the spring balance), and attach a paper clip about 20 cms from the loop to serve as a marker.

2.70/01 Dynamo/Motor

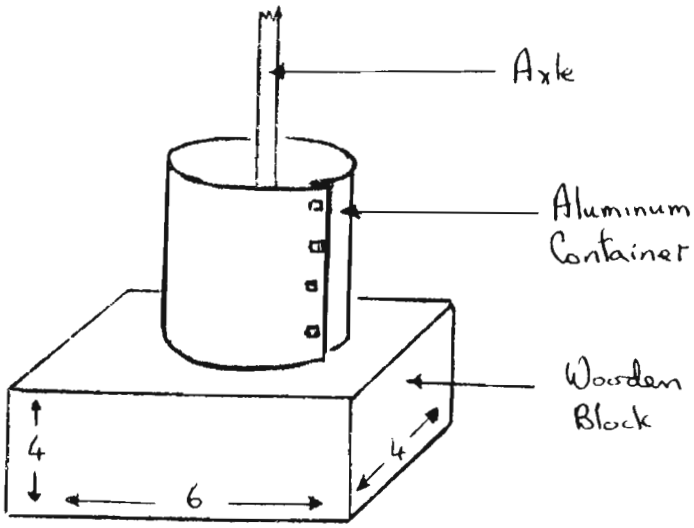


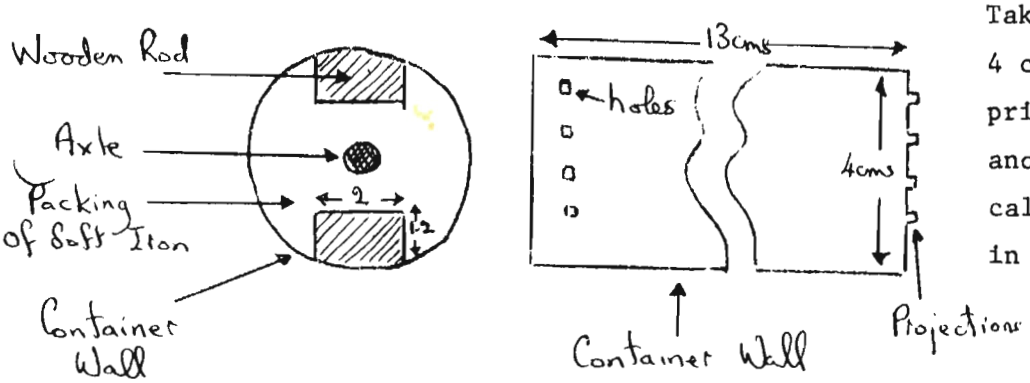
(1) Base

Cut the base out of wood (20 x 15 x 3 cms).

(2) Armature

Take a wooden block, and drill a vertical hole (diameter 0.8 cm) through its center so that it can support a steel axle (15 cms long, 0.7 cms diameter). The latter may be a very long nail with the head removed.

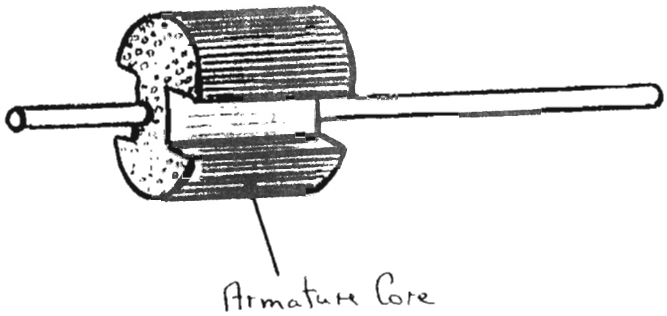


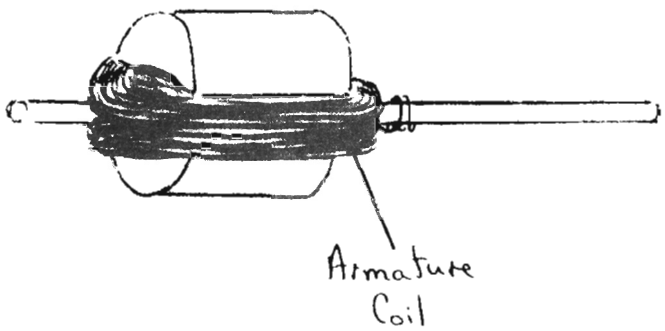


Take a sheet of aluminum (13 x 4 cms) and with the help of an appropriate series of end projections and holes make it into a cylindrical container (4 cms tall, 4 cms in diameter).

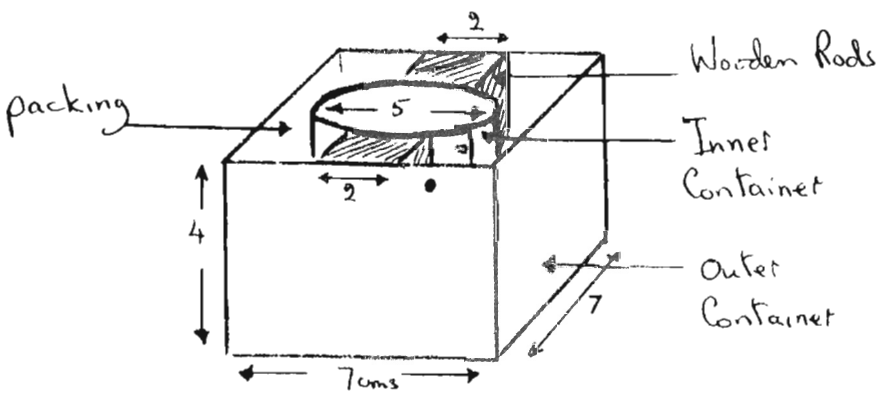
Place the container on the wooden block so that it encircles the axle. Take two wooden rods (4 x 2 x 1.2 cms) and stand these against opposite walls of the container. Now fill the remaining space in the container with 4 cm nails (or similar soft iron material) packed closely side by side and parallel to the axle.

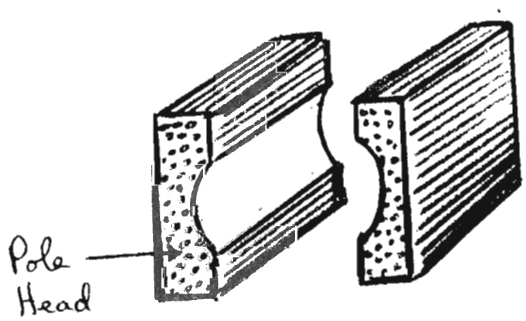
Cover the ends of the nails (not the wood) at both ends of the container with epoxy resin, so that





(3) Pole Heads

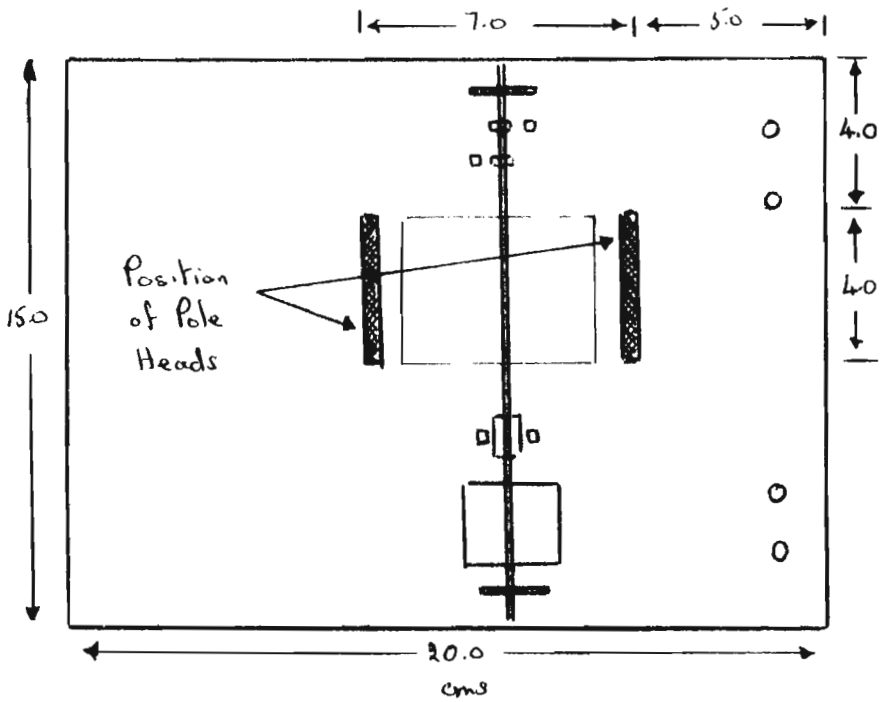




when it dries the nails are welded together into a solid soft iron core penetrated along its axis by a steel axle protruding 4 cms at one end and 7 cms at the other. Remove the aluminum container and the wooden rods. You now have the core of your armature.

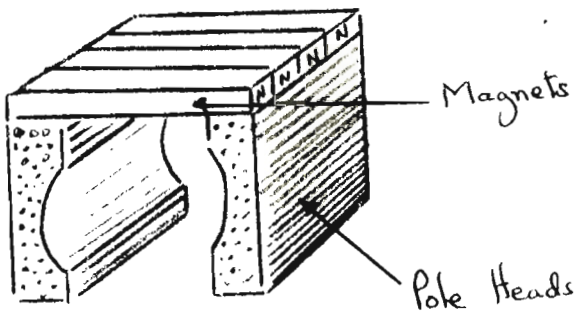
Take a coil of magnet wire (#26) and wind as much as possible into a coil around the core, making sure that you have about 10 cms of both ends left free, having made the coil. Temporarily twist the loose ends around the long end of the axle. The resistance of the coil will be approximately 5 ohms.

The pole heads are made in very much the same way as the armature core. Two open ended containers are required this time, one cylindrical (5 cms diameter, 4 cms long) and one a rectangular cube (7 x 7 x 4 cms). The cylindrical one is placed inside the rectangular one, and the two held apart by two wooden rods (2 x 1 x 4 cms). Just as when making the armature core, pack the space between the two containers with 4 cm long nails, packed parallel to the axis of the cylindrical container. Cover the nail ends at both extremities of the containers with epoxy resin. When this has dried remove the two containers and the wooden rods. You will now have two pole heads.

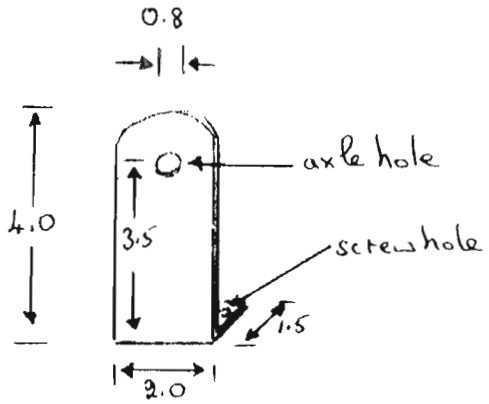


Place the pole heads on the base in the positions illustrated, and attach them firmly to the base with the help of epoxy resin.

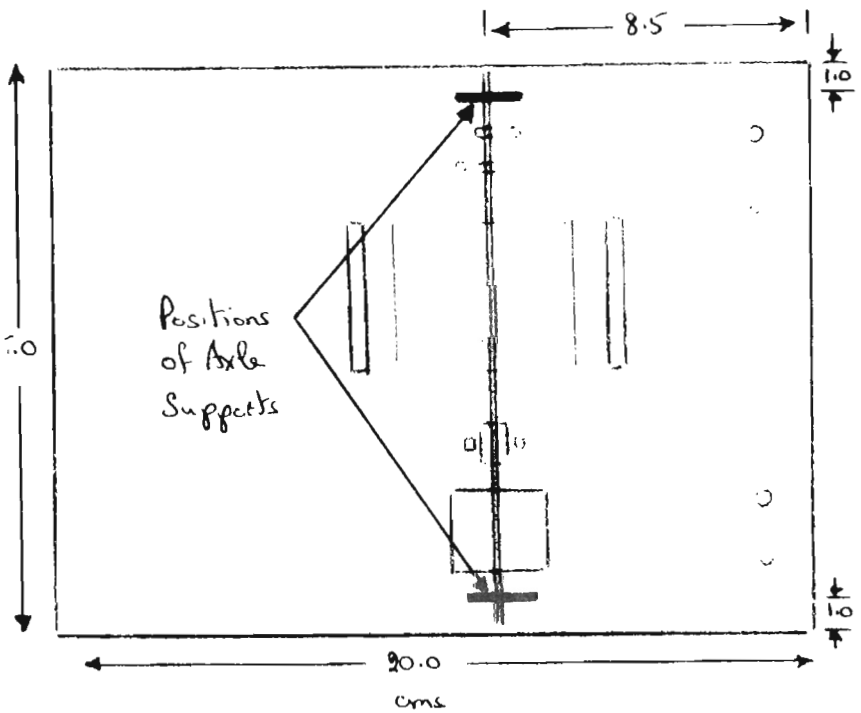
Complete the system with 4 very strong magnets (7 x 1 x 1 cm) laid parallel to one another (North Pole touching North Pole) across the gap between the pole heads. The magnets may be purchased, or made as described in the electromagnetism section.



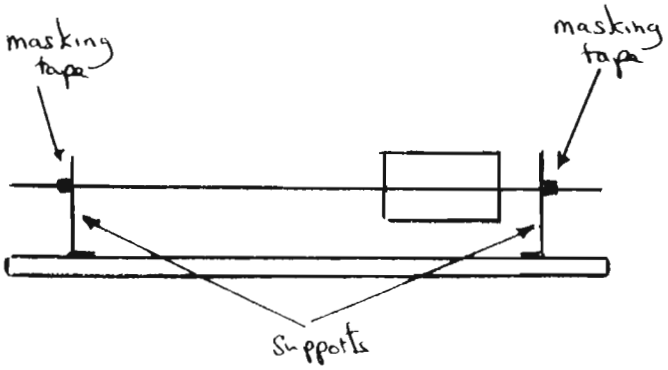
(4) Axle Supports



Make two axle supports out of brass sheeting (0.2 cms thick), drilling one hole (0.8 cms diameter) in the upright portion to take the axle, and two holes (0.3 cms diameter) in the base portion to take two screws.

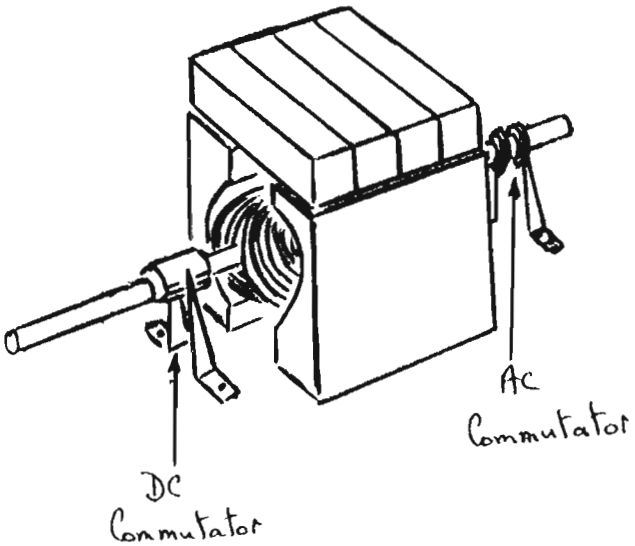


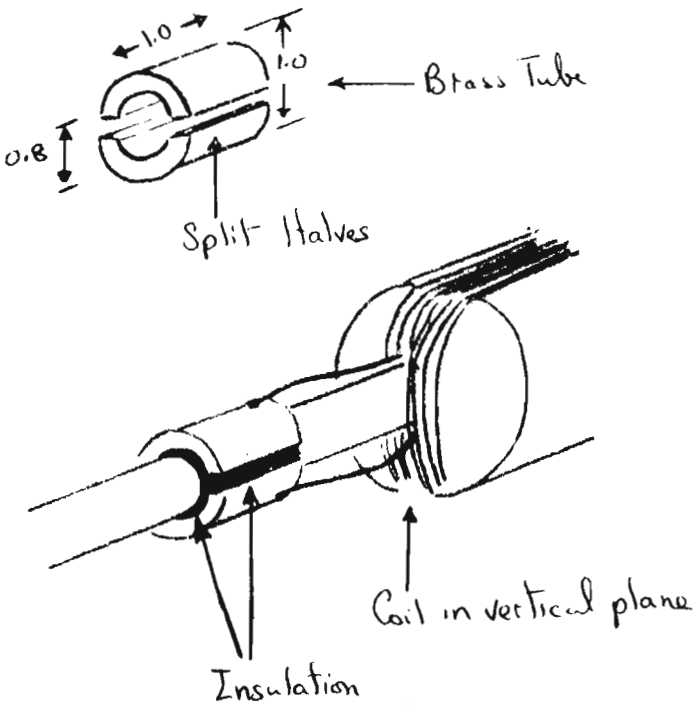
Slide the supports on to either side of the axle, and attach them firmly to the base of the apparatus in the positions shown.



The axle may be held firmly in position by winding masking tape (not scotch tape) around the axle next to, and just outside, the supports.

(5) Commutators

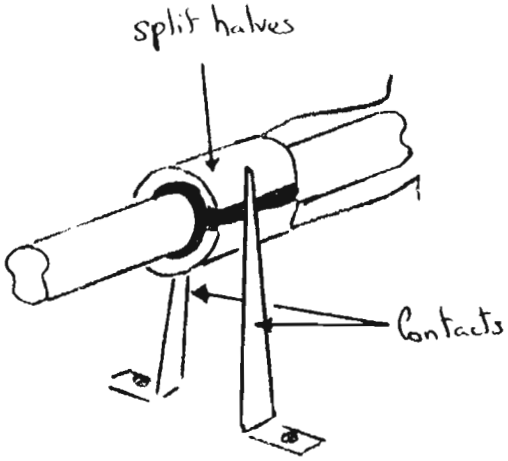




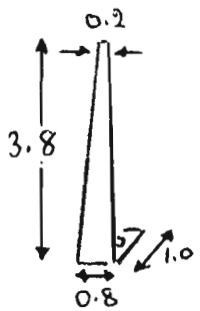
(i) To make the DC commutator take a piece of brass tubing, and cut it to make two halves.

Take some epoxy resin, which is a good insulator, and coat all the inner surfaces of the two halves with resin about 0.1 cm thick.

Rotate the armature coil until it is in a vertical plane, and then attach the two split halves to the axle so that the split between the halves is in a horizontal plane. If the epoxy resin is thick enough it will not only attach the split halves firmly to the axle, but will also insulate the two halves from one another, and from the axle itself.

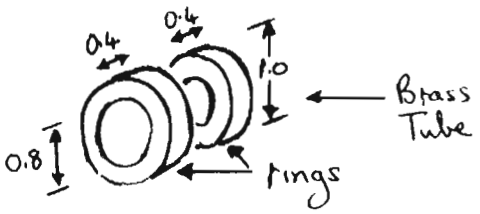


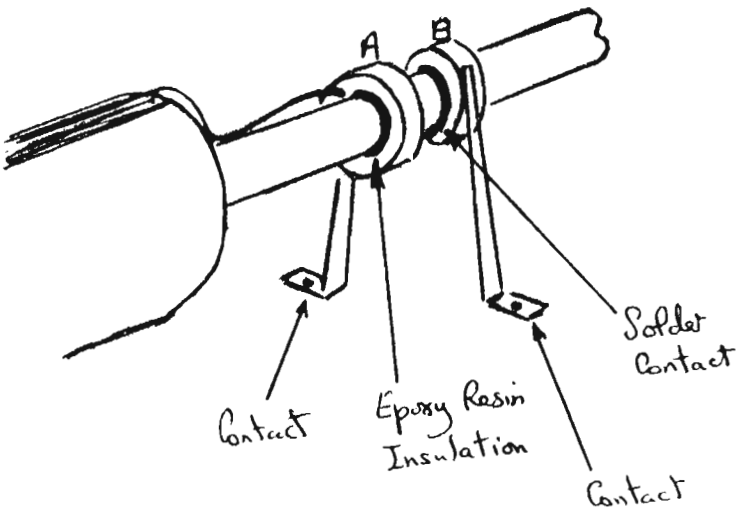
Take the two loose wires from the armature coil and, after cleaning the ends with sandpaper, solder one to one split half and the other to the other split half.

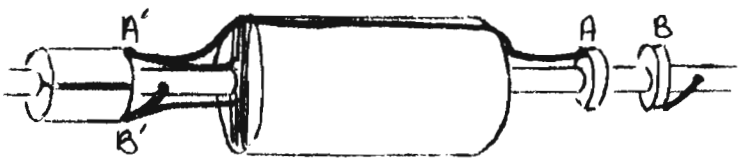


Cut two identical contacts out of thin brass sheeting (0.1 cms thick) as shown. Attach these to the base of the apparatus with screws, so that they are in spring contact with opposite sides of the split halves.

The DC commutator is now complete.







(ii) To make the AC commutator take a a piece of brass tubing and cut two identical rings from it.

Temporarily remove the axle support and slide the two rings on to the axle. Coat a length of axle (0.5 cms long) with epoxy resin about 0.1 cm thick and slide ring A into position over this. The epoxy resin should be such as to insulate the ring from the axle as well as to hold it firmly in position.

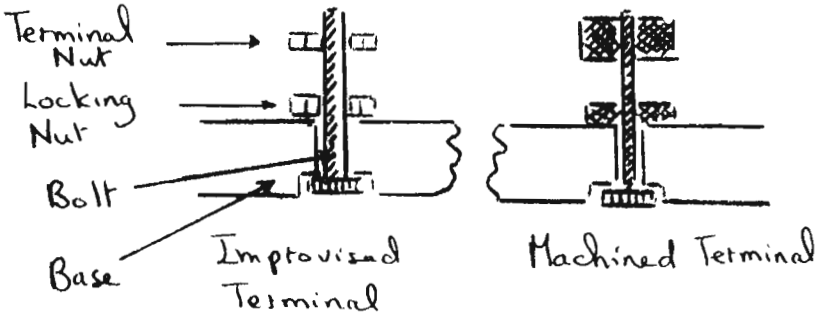
Ring B is soldered to the axle about 0.5 cms from ring A. Solder insures good electrical contact between the ring and axle. Two contacts, identical to those made for the split halves, should be cut from brass, and attached to the base so that each is in spring contact with one of the rings.

Connect ring B electrically to one of the split halves (B') by soldering a very short length of magnet wire (#26) from ring B to the axle and split half B' to the axle. Don't forget to clean the ends of the magnet wire with sandpaper prior to soldering.

Connect ring A electrically to the other split half A' by soldering a length of magnet wire (#26) from one to the other.

The AC commutator is now complete.

(6) Terminals and Electric Wiring



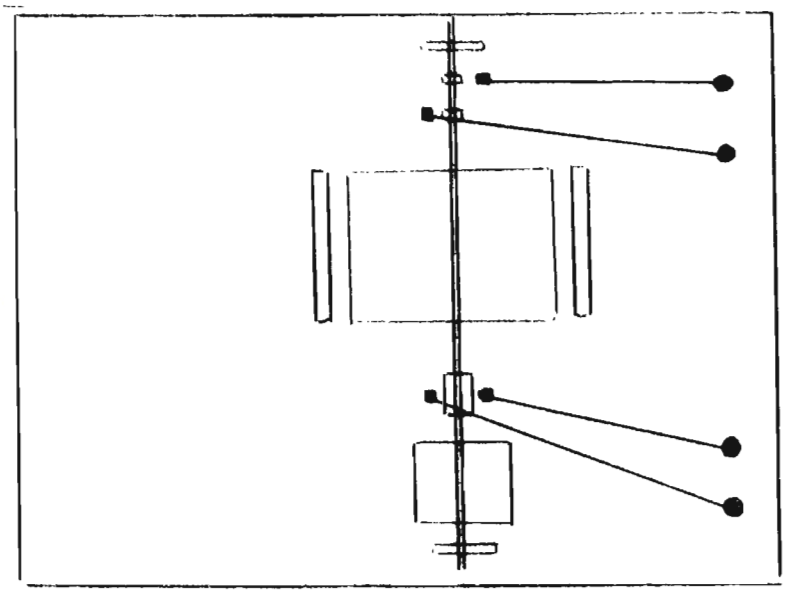
Drill 4 holes through the base to take 4 terminals, two to serve as an AC outlet and two as a DC outlet.

Make each terminal as follows. Insert a brass bolt (2.5 cms long, 0.3 cms diameter) through the hole, and attach two nuts, one to serve as a locking nut and one as a terminal nut.

It is of course very nice to have fairly large nuts which can easily be adjusted with the fingers. Such nuts are probably best made on a metal lathe. The nuts might both be 1 cm in diameter, with the thickness of the terminal nut being 0.5 cms and that of the locking nut 0.2 cms.

Fahnstock Clip

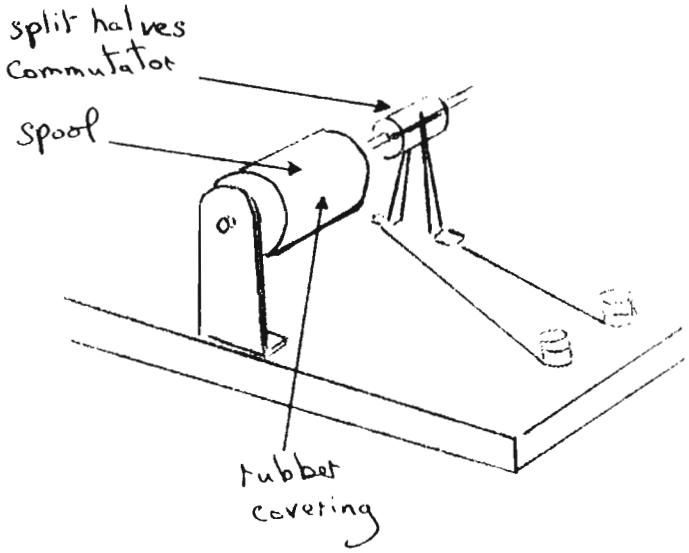
In some localities it is cheaper to purchase terminals on the local market. Check the availability of such items as Fahnstock clips which can replace the above



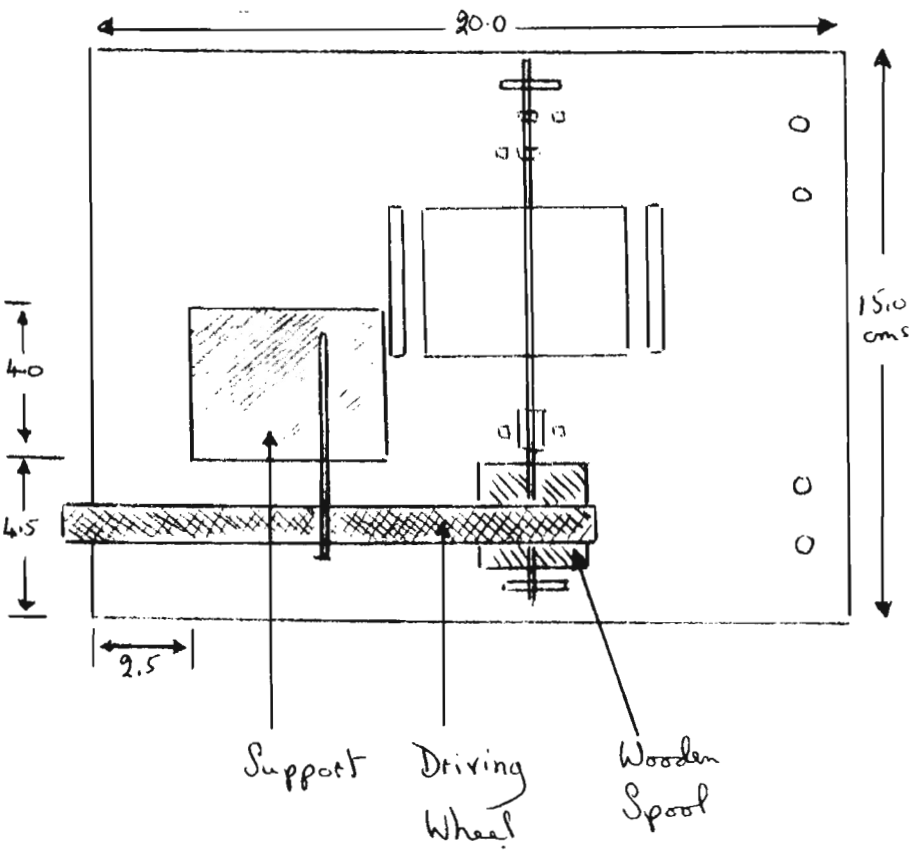
● Terminals
■ Contacts

Take some magnet wire (#26), clean the ends with sandpaper, and then connect the terminals to the contacts as illustrated, fastening the wire beneath the screw of the contact and beneath the locking nut on the terminal.

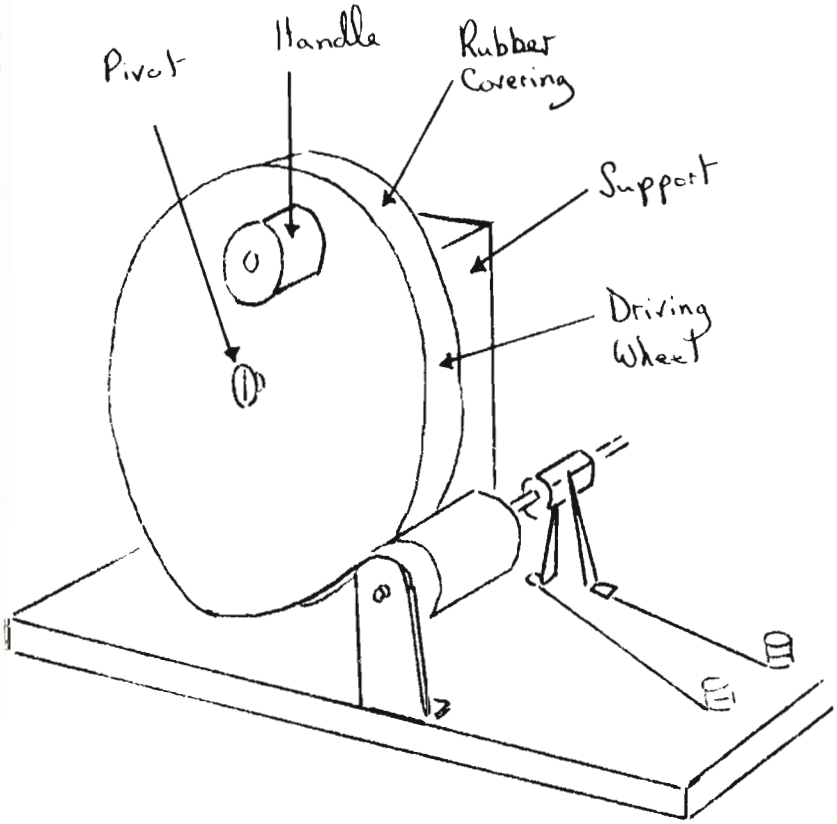
(7) Driving Wheel System



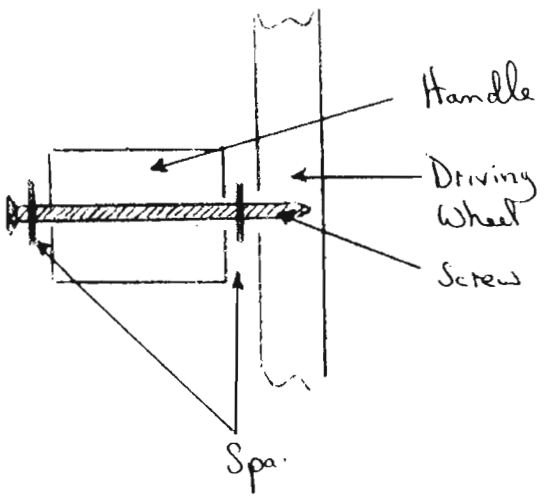
Take a wooden spool (3 cms diameter, 2.5 cms long) and fill the central hole with wood putty. When the latter is perfectly dry drill a new hole (0.7 cms diameter) along its axis so that it will just fit on the armature axle. Cut a rubber strip (2.5 by 9.5 cms) from an old car inner tube, and nail it around the perimeter of the spool. Temporarily remove the appropriate axle support, and attach the spool firmly to the axle with epoxy resin.



Cut a wooden support (12 x 5 x 4 cms) for the driving wheel, and locate it on the base in the position shown. Cut a slight inset (0.2 cms) into the base to hold the bottom of the base firmly, and put some wood cement in the inset. Fasten the support firmly in position with the help of two wood screws passing through the base of the apparatus.

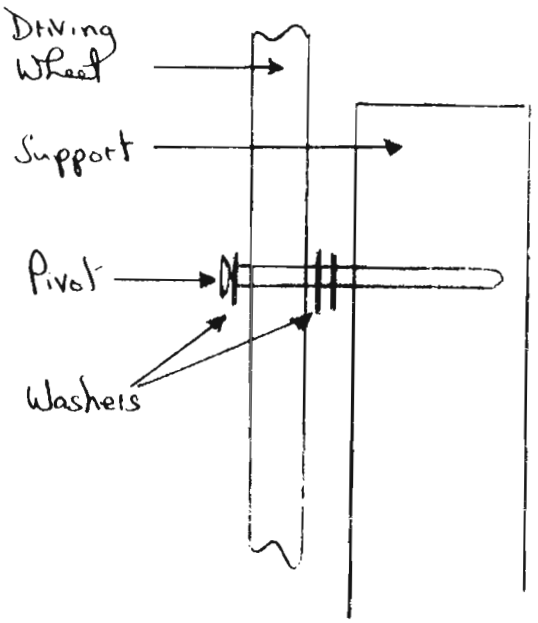


Cut a wooden disc (15 cms diameter, approximately 1.5 cms thick) to serve as the driving wheel. Cut a rubber strip (1.5 x 44 cms) from an old car inner tube, and nail it around the perimeter of the disc. Drill a hole (0.8 cms diameter) through the center of the disc, and pass a nail (0.7 cms diameter, 6 cms long) through it to serve as a pivot.



Take another wooden spool (2.5 cms diameter and 2.5 cms long) and a screw (4.0 cms long). Drill a hole along the axis of the spool so that the spool fits loosely on the screw, but cannot slip over the screwhead. Screw the spool onto the driving wheel about 4 cms from the perimeter. Locate washers either side of the spool to permit it freedom of motion. You now have a handle for the driving wheel.

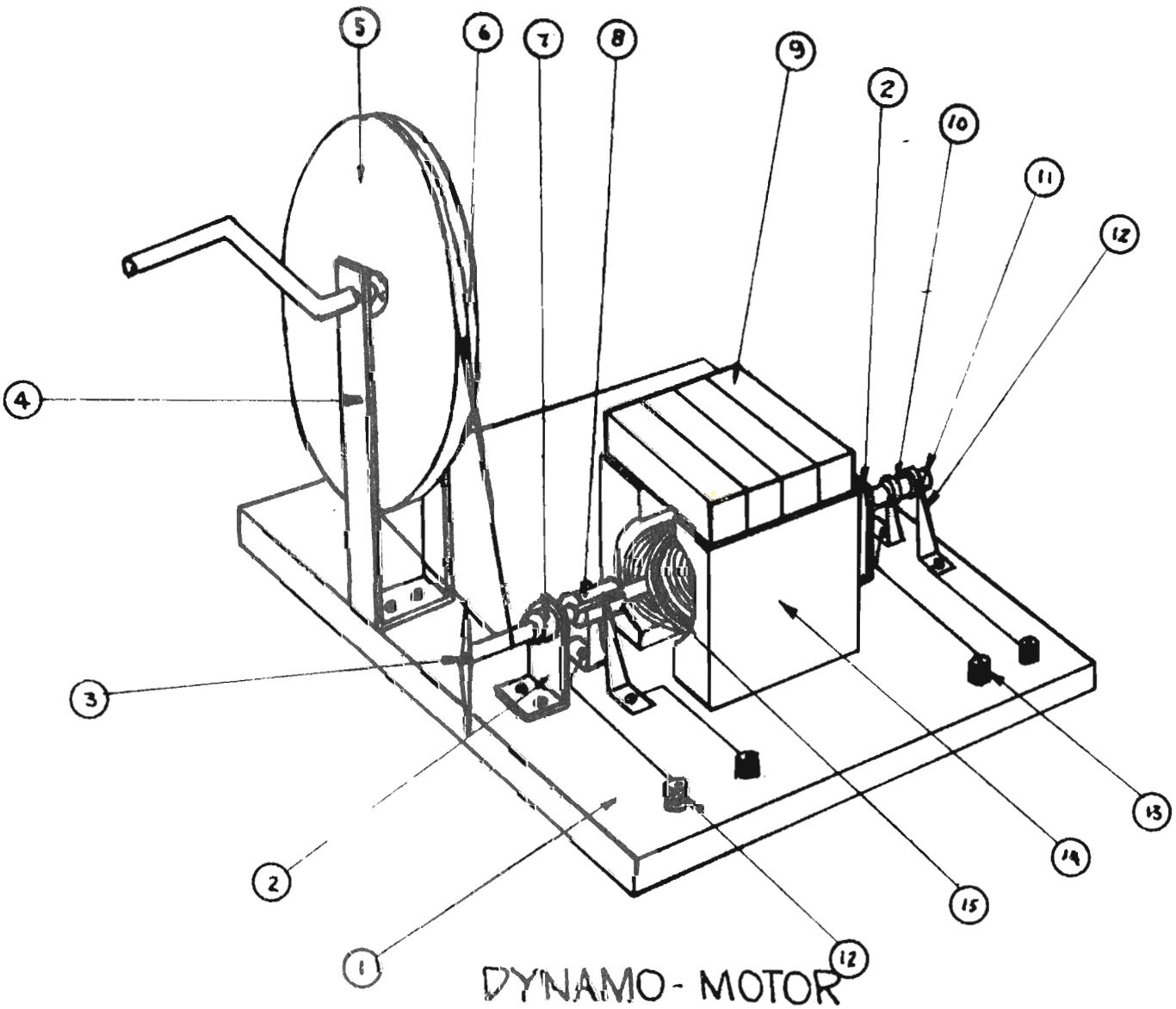
Washers should be similarly placed on the pivot, either side of the driving wheel.



Finally, hold the driving wheel tight against the axle spool, and use the pivot to mark the best position to locate it permanently in the support. This will be at a height of approximately 10 cms on the support. Drill a horizontal hole (diameter 0.7 cms) into the support, and fix the pivot firmly in the hole with epoxy resin.

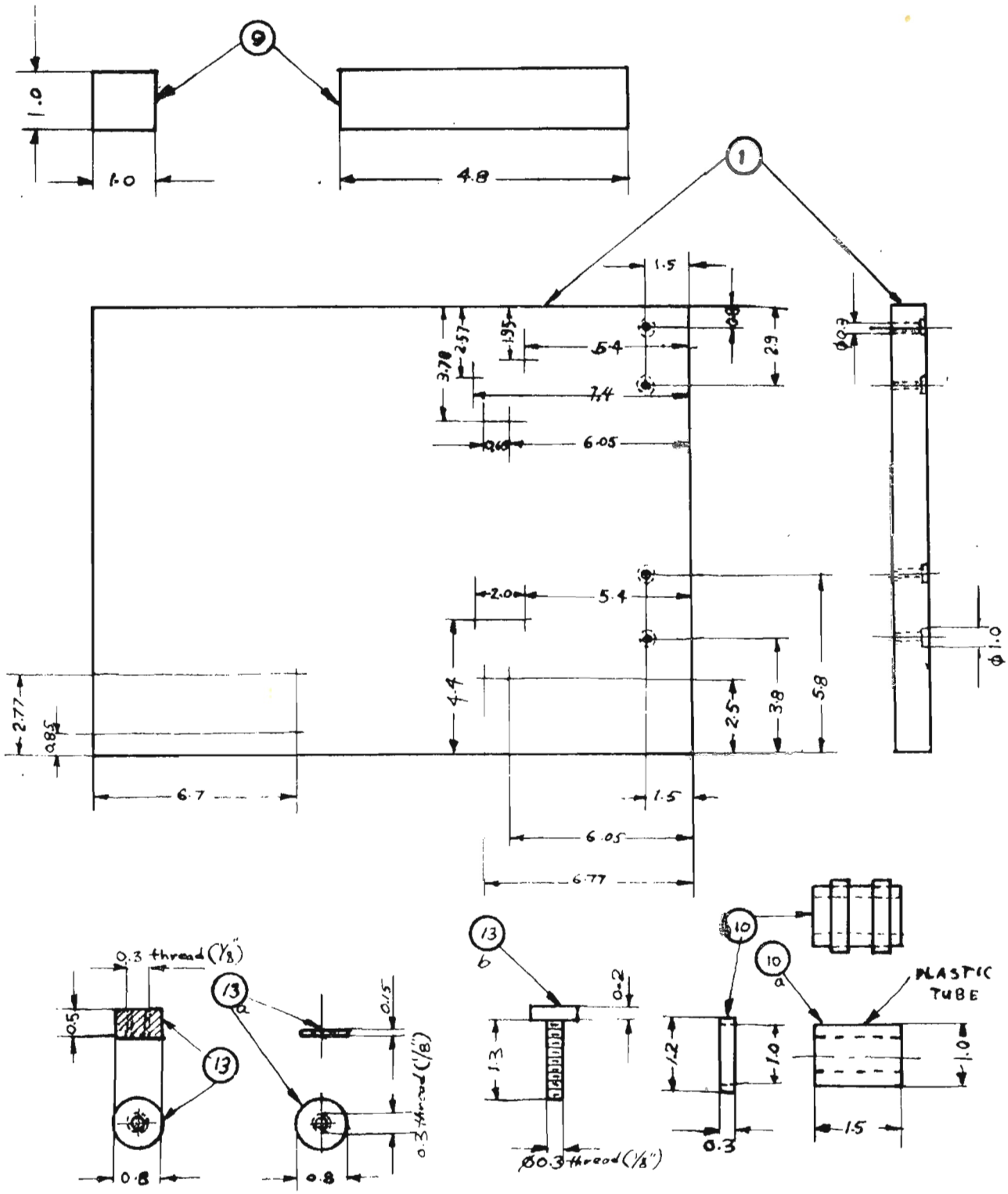
Your dynamo/motor is now ready for operation.

2.70/02 Dynamo / Motor

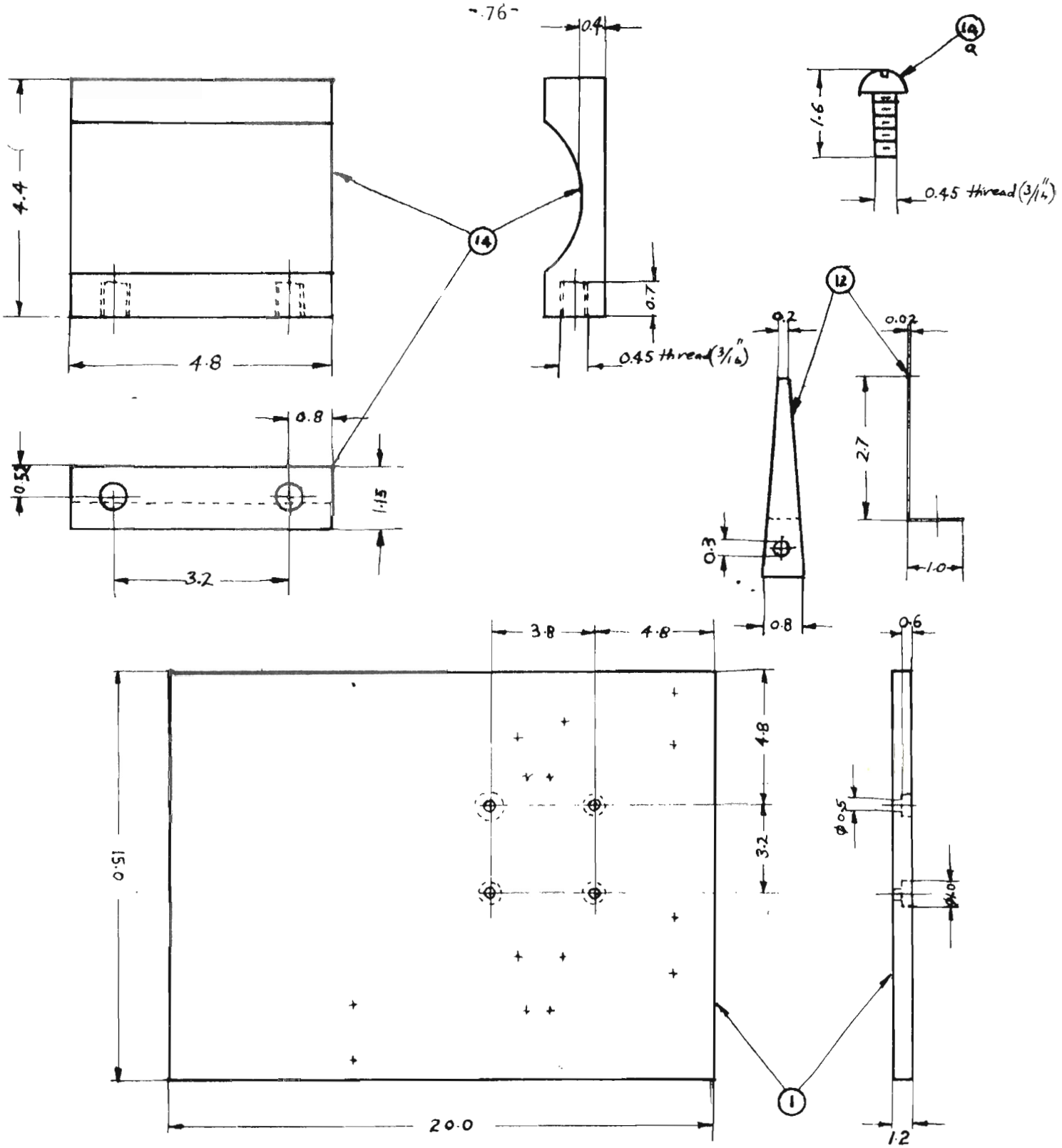


DYNAMO - MOTOR

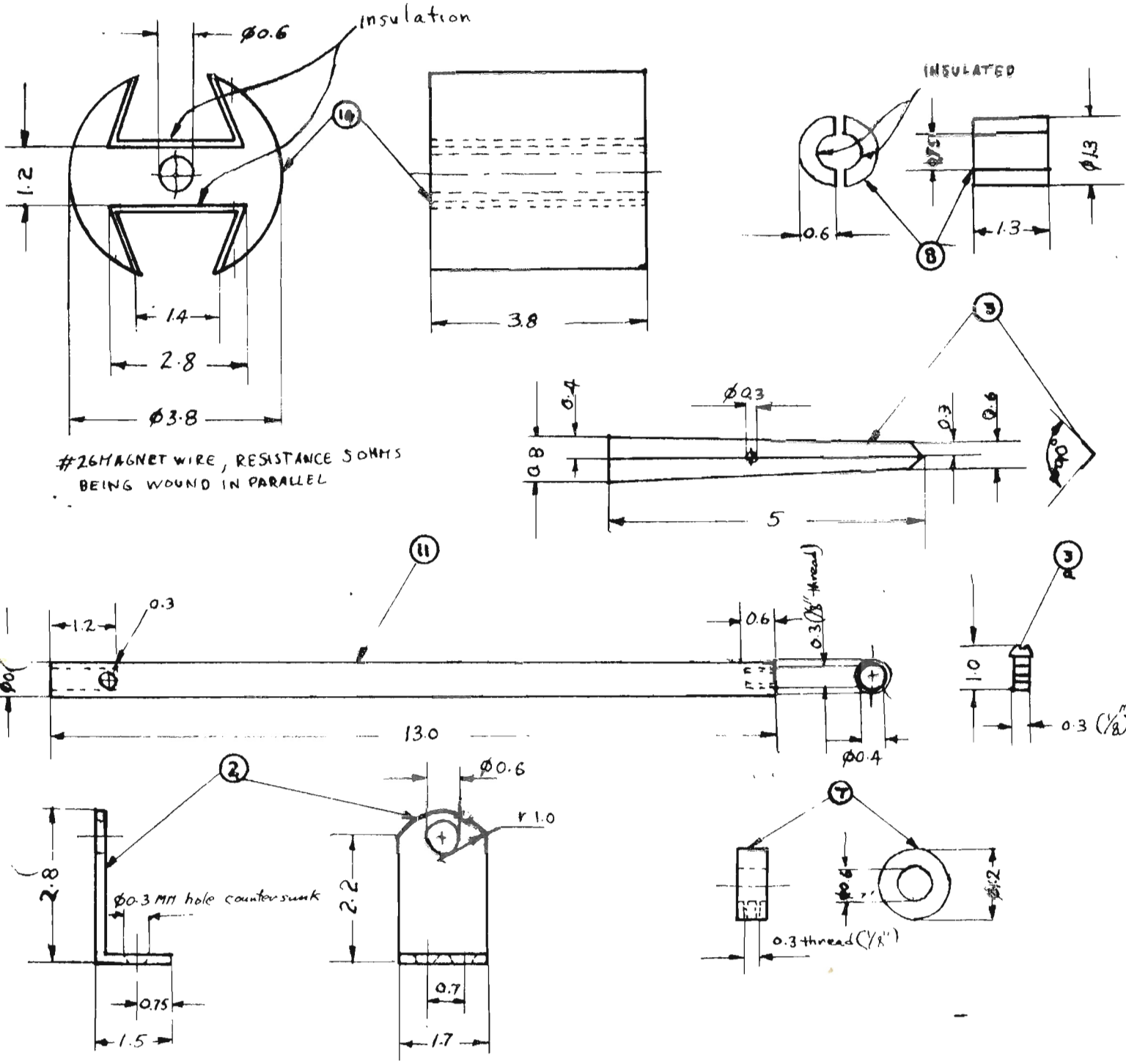
PART NO.	DESCRIPTION	DIMENSIONS	QUANTITY
1	BASE - (NARRA) WOOD	1·2×15·0×20·0	1
2	AXLE SUPPORT - BRASS	0·15×1·7×3·3	2
3	INDICATOR - BRASS	0·05×0·8×5·0	1
4	HAND WHEEL SUPPORT - STEEL	0·3×1·2×24·0	1
5	HAND WHEEL - (NARRA) WOOD	ϕ13·5×1·2	1
6	RUBBER BAND	13·0 long.	2
7	STOP RING - BRASS	ϕ1·2×0·5	1
8	INSULATED SPLIT RING - BRASS	ϕ1·2×1·3	1
9	RECTANGULAR MAGNETS - TOOL STEEL or ALNICO	1·0×1·0×4·8	4
10	INSULATED DOUBLE RING - BRASS	ϕ1·2×0·3	1
11	AXLE - STEEL	ϕ0·6×13·0	1
12	ELECTRICAL CONTACT - BRASS	0·02×0·8×3·7	4
13	TERMINAL - BRASS	ϕ0·8×3·7	4
14	POLE HEAD - STEEL	1·2×6·4×ϕ8	2
15	ARMATURE - STEEL	ϕ3·8×3·8	1



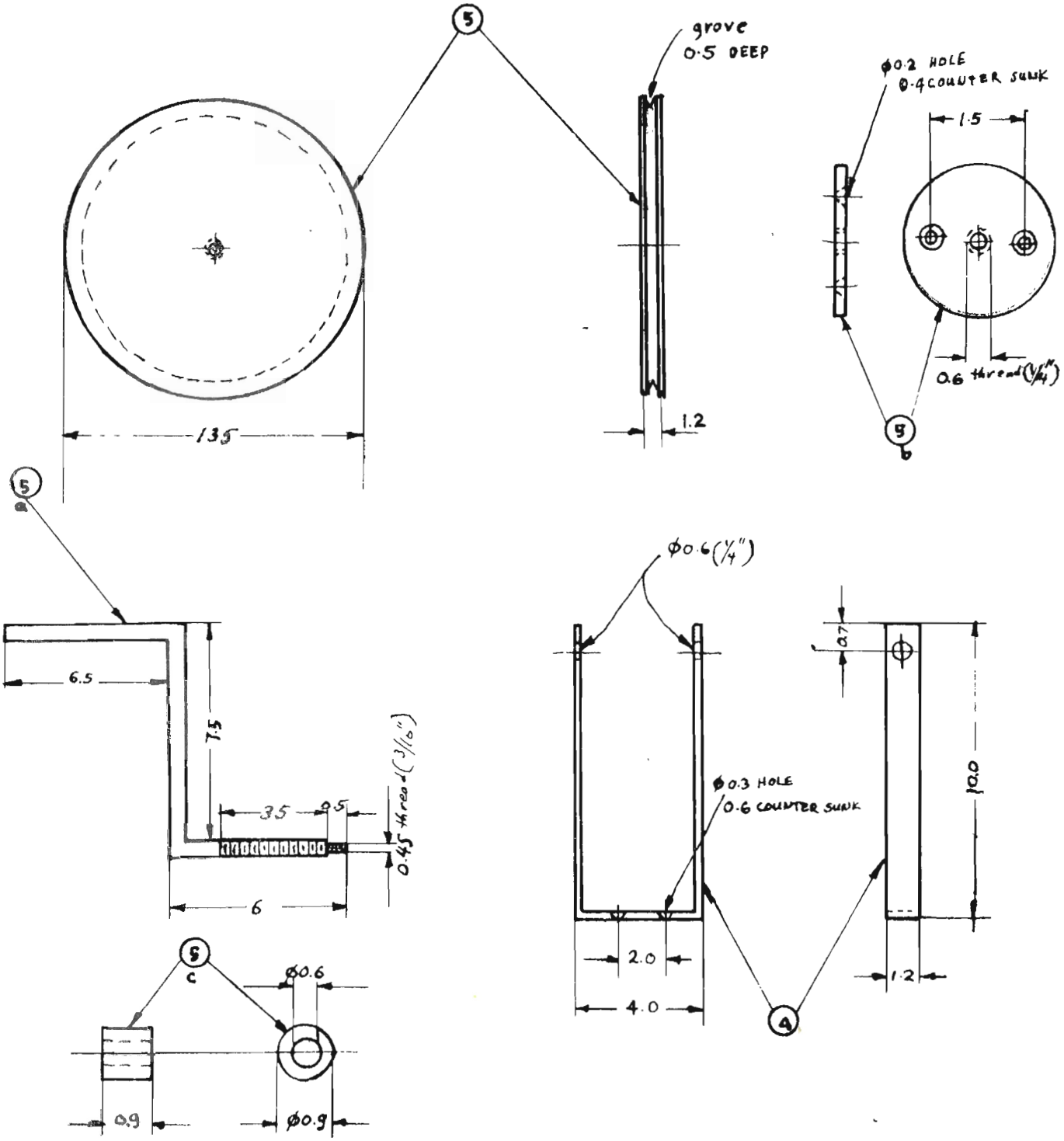
PART NO.	DYNAMO-MOTOR PARTS 1-9-10-13	SCALE
1	BASE	2:1
9	RECTANGULAR MAGNET	1:1
10-a	INSULATED DOUBLE RING w/ PLASTIC TUBE	1:1
13-a-b	TERMINAL - BRASS NUT W/ KNURLING WASHER NUT and SCREW	1:1
+	WOOD SCREW LOCATION	
ⓐ	TERMINAL LOCATION	



PART NO.	DYNAMO-MOTOR PARTS 1-12-14	SCALE
1	BASE	2:1
12	ELECTRICAL CONTACT, 4 PIECES	1:1
14	POLE HEAD, 2 PIECES	1:1
14a	STEEL BOLTS, 4 PIECES	1:1

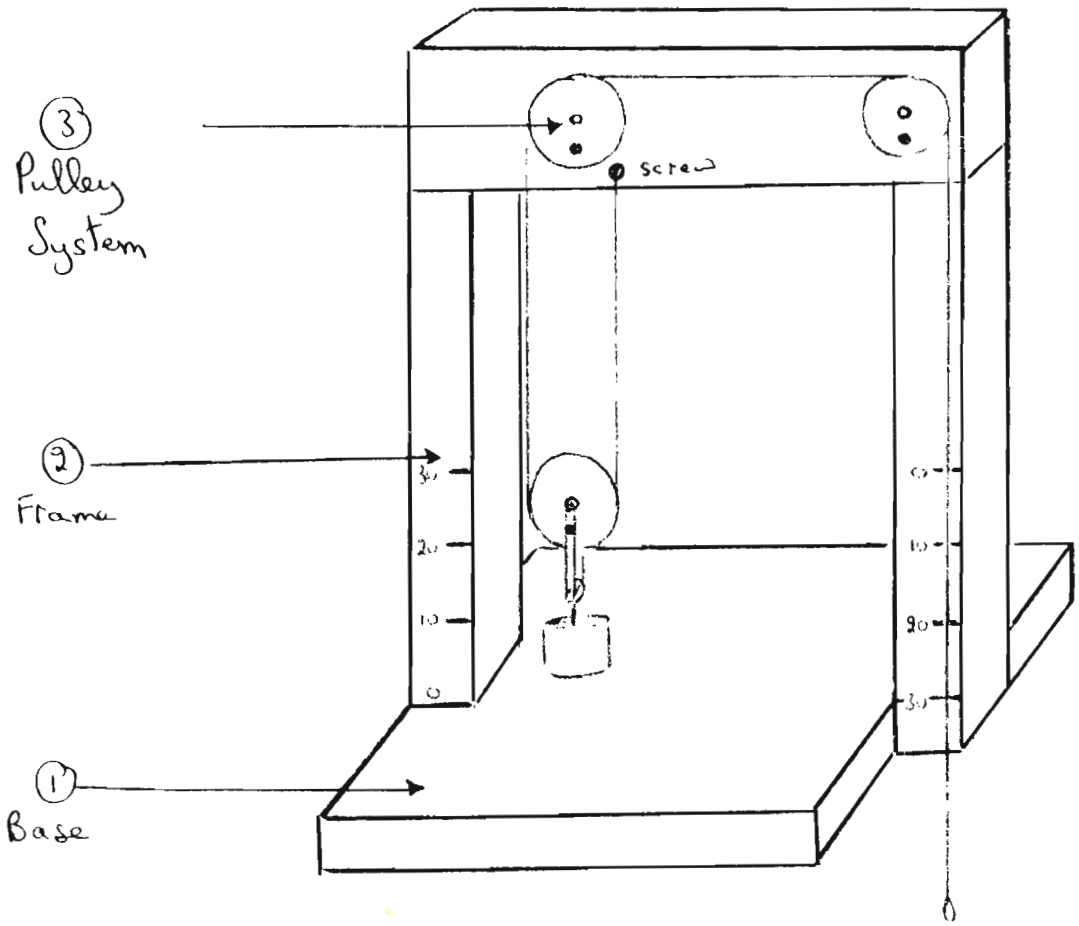


PART NO.	DYNAMO - MOTOR PARTS 2-3-7-8-11-14	SCALE
2	AXLE SUPPORT, 2 PIECES BRASS SHEET	1:1
3	INDICATOR - BRASS SHEET	1:1
3a	SCREW - BRASS	1:1
7	STOP RING WITH SCREW	1:1
8	INSULATED SPLIT RING - BRASS	1:1
11	AXLE - STEEL ROD	1:1
14	ARMATURE - STEEL	1:1

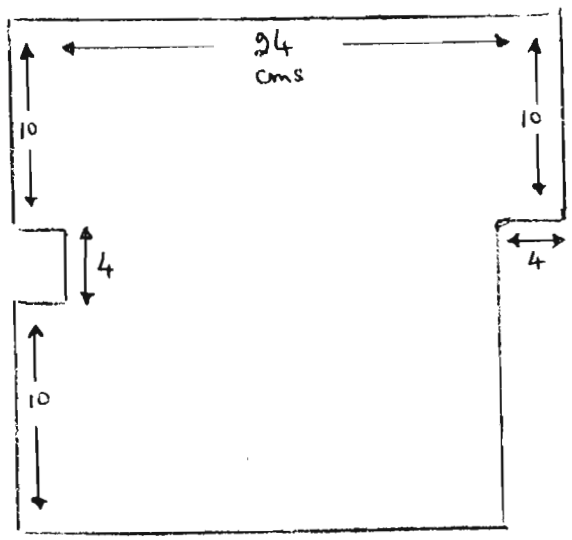


PART NO.	DYNAMO-MOTOR PARTS 4-8	SCALE
4	HAND WHEEL SUPPORT - FLAT BAR	2:1
5	HAND WHEEL - (NARRA) WOOD	2:1
5a	HAND LEVER - STEEL ROD	2:1
5b	BRASS SHEET	1:1
5c	BRASS SPACER, 0.6 (¼") NUT, 2 WASHERS & 1 WINGNUT	1:1

2.70/03 Simple Machine

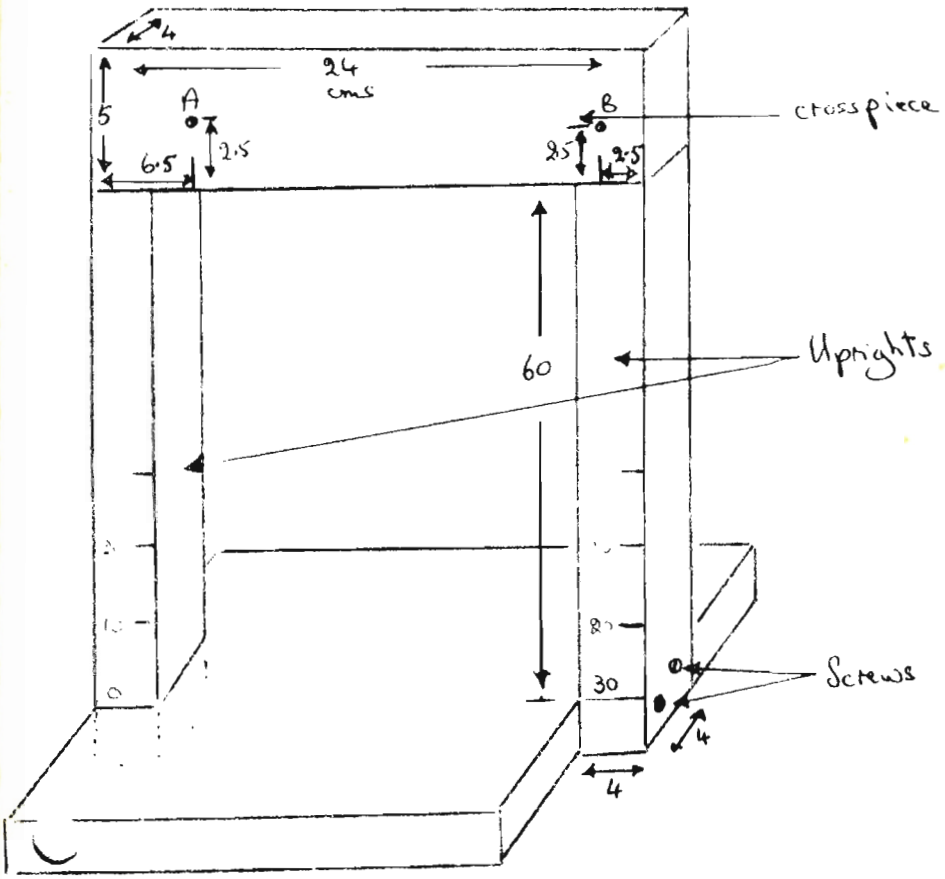


(1) Base



Cut the base from a piece of wood (24 x 24 x 2.5 cms), providing the apparatus with a firm base.

(2) Frame

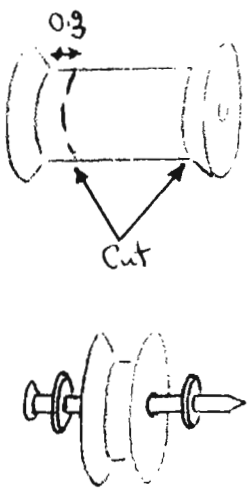


Attach two uprights (63 x 4 x 4 cms each) firmly to the base with wood cement and screws.

Sit the crosspiece (24 x 5 x 4 cms on top of the uprights, and fasten firmly with wood cement.

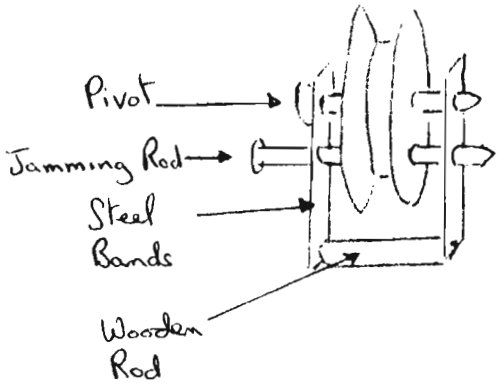
Mark two scales of 30 cms each on paper, and fix to the uprights in the positions shown.

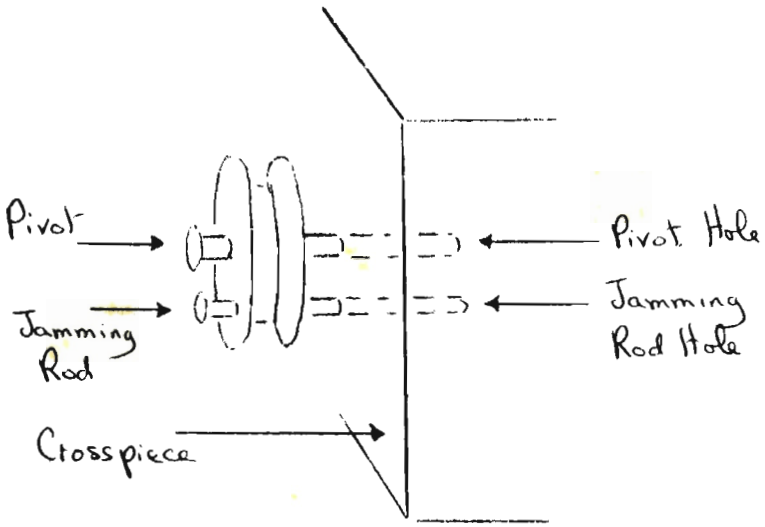
(3) Pulley System



Take a spool (approximately 4 cms diameter) and cut off the two ends The two extremities may be attache to one another with wood cement to form a pulley. Make two more pulleys in exactly the same way.

Bore two horizontal holes (0.7 cms diameter) into the crosspiece in the positions marked A and B, and use nails (0.7 cms diameter) to fix two of the pulleys to the cros piece in these positions. Make su that the pulley hole is big enough to permit it to move freely on the nail. Place washers either side of each pulley.



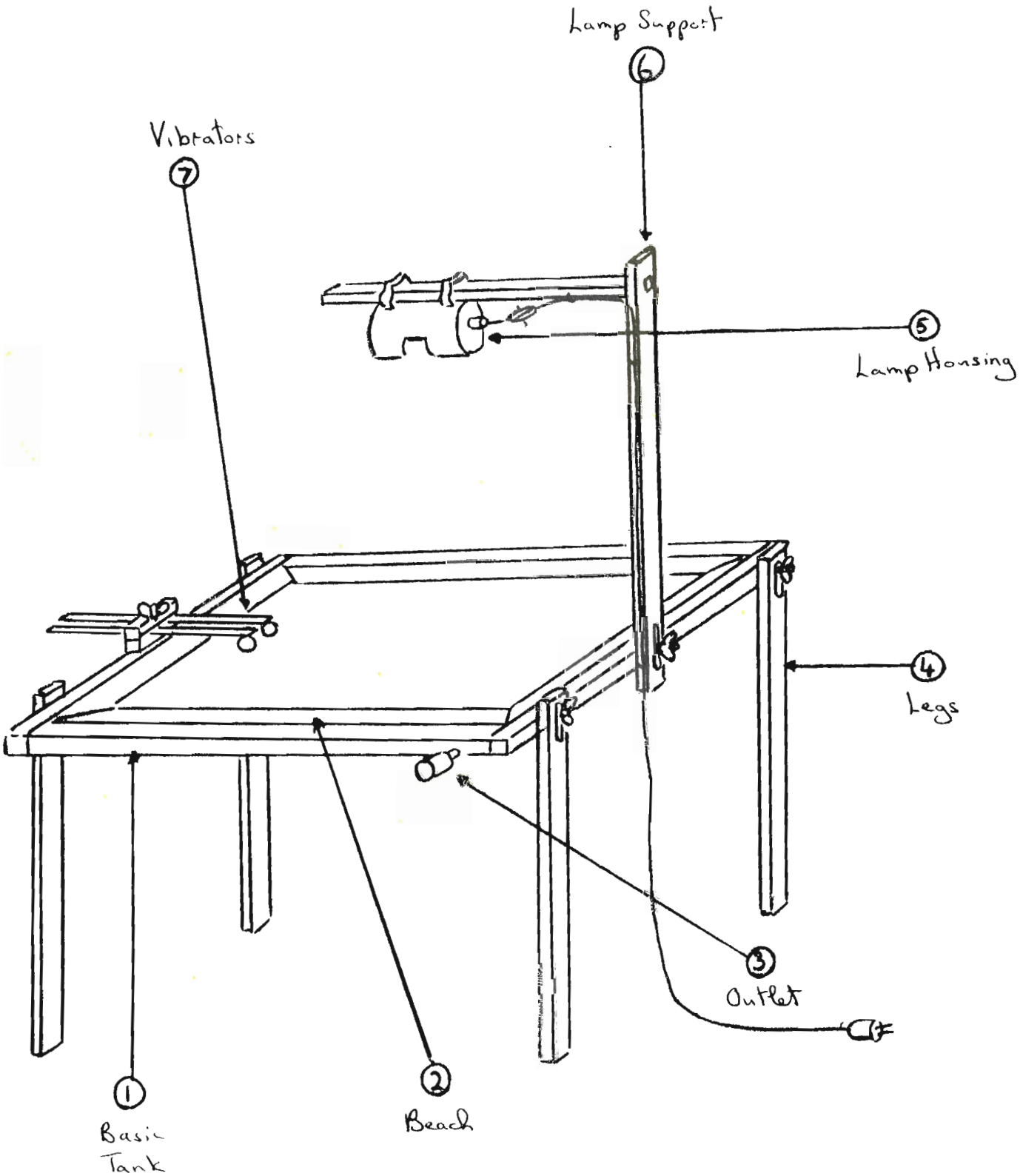


The third pulley must be able to lift masses. With this in mind cut two steel bands (packing case bands, 2.5 x 1 cm) and drill holes (0.8 cms diameter) to take the pivot nail (0.7 cms diameter). Fasten the free ends of the two bands to a short wooden rod 0.8 cms diameter, 1.2 cms long) with epoxy resin.

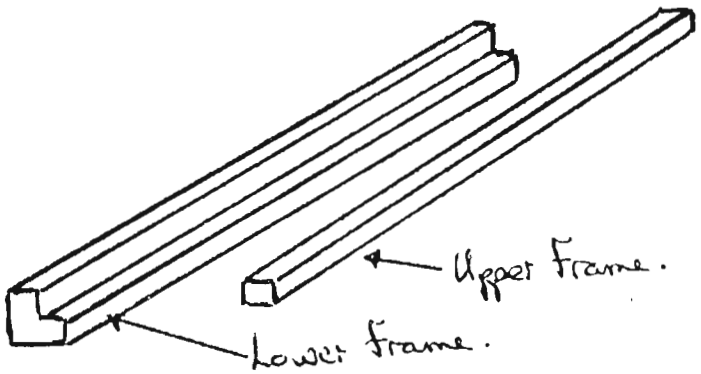
Now drill a hole (approximately 0.3 cms) through each pulley, fairly close to its perimeter, to take a nail intended to serve as a "jamming rod". Drill corresponding holes in the crosspiece and the steel bands of the third pulley arrangement, so that any single wheel might be locked in position by insertion of a "jamming rod" through the pulley and into the corresponding hole in the crosspiece, or steel bands.

Take a 2 meter length of string and attach one end to a screw in the crosspiece. Wind the string around the three pulleys as illustrated, keeping the string taut by suspending masses from the third pulley and from the free end of the string Since this simple machine has been designed to illustrate problems due to friction a coarse string (as opposed to a smooth nylon string) is preferred.

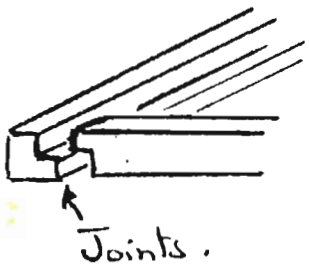
3.10/01 Ripple Tank



(1) Basic Tank

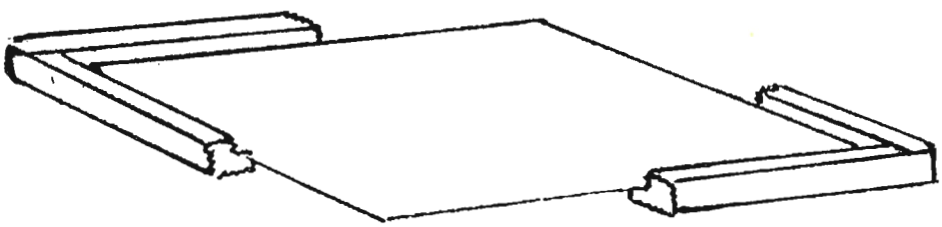


To make the frame of the ripple tank (60 x 60 cms), take 4 pieces of wood, each 60 cms long and of cross section approximately 3.5 by 3.5 cms. Out of each side cut a single length approximately 2.0 by 2.0 cms. (A small circular saw is useful in performing this task). You now have 4 large pieces of wood to make the lower frame, and 4 small pieces to make the upper frame.

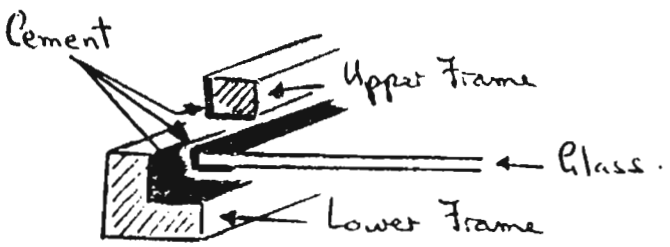


The end pieces of the lower frame are cut (as illustrated) so that they may be firmly joined together with wood cement.

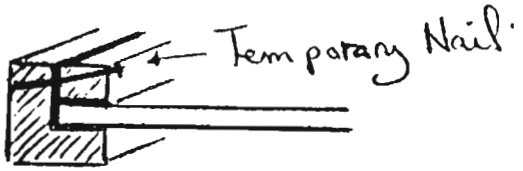
Cut a glass plate (0.3 cms thick) so that it will sit on the ledge of the lower frame.

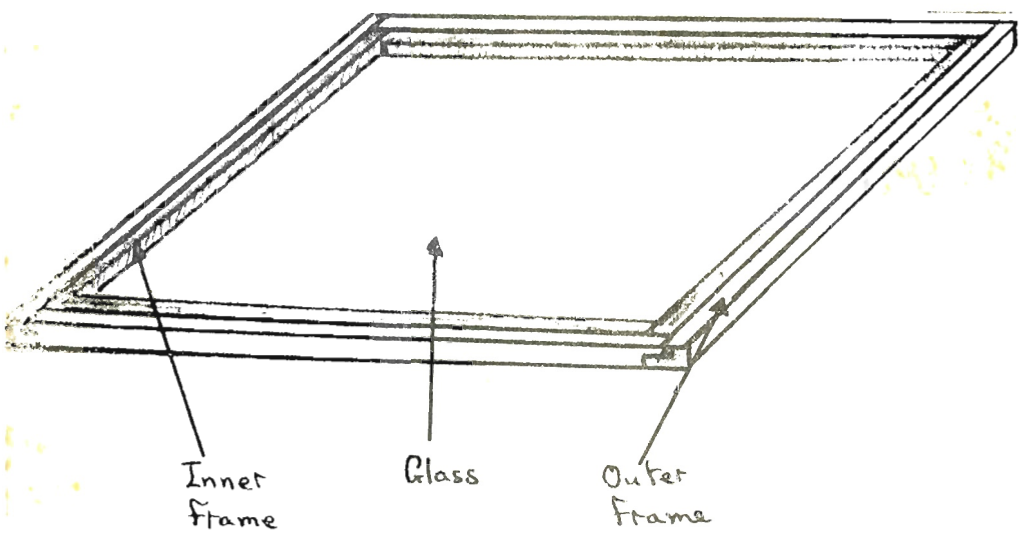


Cover the edges of the glass, and the inner edges of the lower and upper frame with a waterproof cement as illustrated. An asphalt or rubber based cement is ideal. Sit the glass on the ledge of the lower frame, and hold it in position by placing the upper frame on top of it.



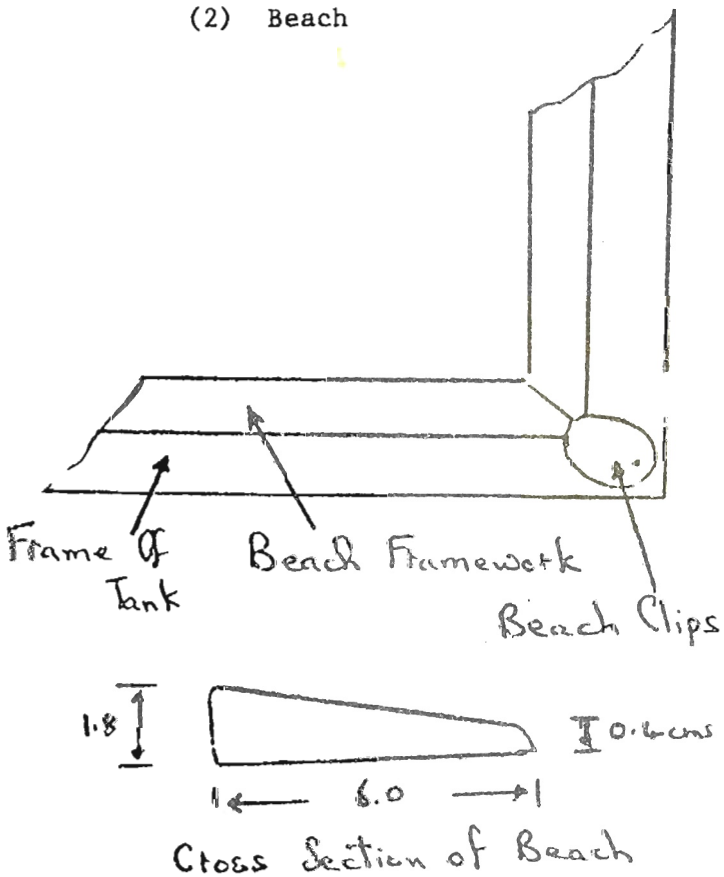
The whole frame may be held together by clamps, or nails tacked temporarily through the two frames, until the cement is dry.





You now have a basic tank with an inner and outer frame insuring the tank is leak proof.

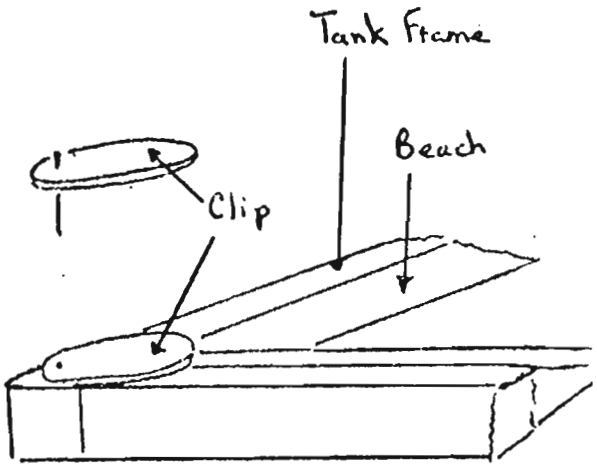
(2) Beach



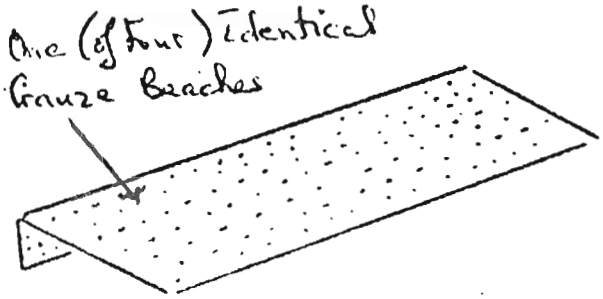
The beach is any device which will cut out unwanted reflections from the sides of the tank. One of the most effective, and durable of beaches is made from soft pine wood (packing case material). Mak the beach rather like a picture frame so that it sits on the glass surface of the tank, and fits snugly within the upper frame.

The most important aspect of the beach is the angle of the surface as it slopes downward from its outer to inner edge. The dimensions of a cross section to cope with water depths varying from 0.5 to 1.5 cms is illustrated.

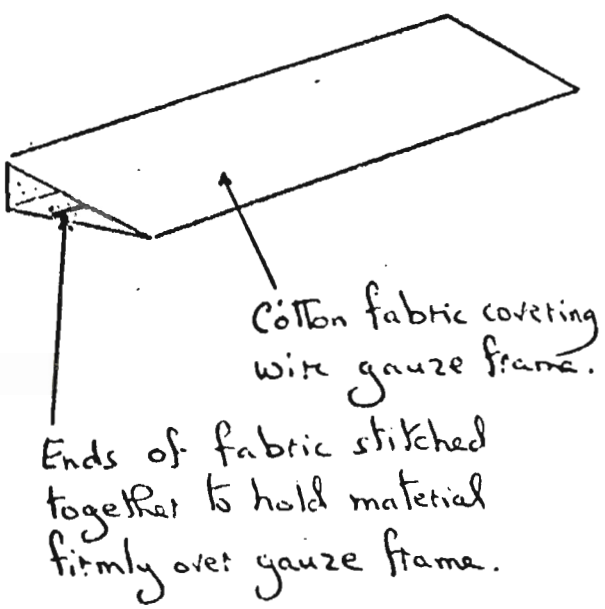
Smooth the surface of the beach with fine sandpaper (leaving a smooth, but porous, surface), but do not varnish. Wetting the surface of the beach at the commencement of a series of experiments makes the damping of the waves most effective.



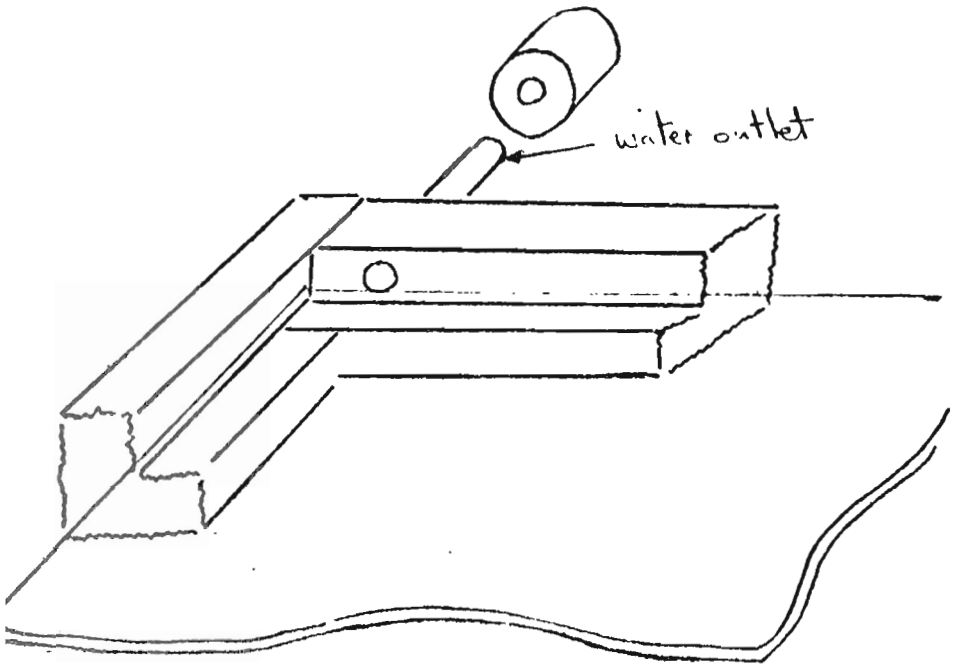
Prevent the beach frame from floating by making 4 metal clips to attach to the corners of the ripple tank frame. Pivot each clip around a nail so that the beach can readily be released.



Beaches may be made from many alternative materials. Fine wire gauze is frequently used for this purpose, but on its own is not as effective as the wooden beach. However, if the surface of the wire gauze is covered with cotton cloth an extremely good beach is created. The only problem is that the cloth must be replaced periodically.



(3) Outlet

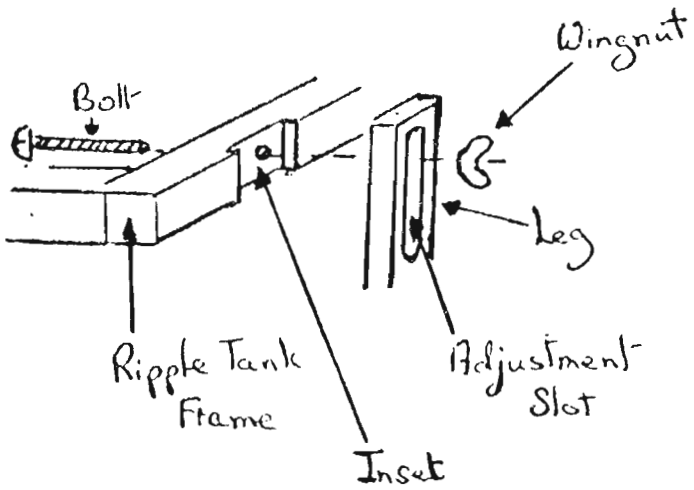


A water outlet is not absolutely essential, but it does make the draining of water from the ripple tank so much simpler, and prevents the spilling of water all over the floor.

Cut a short length of aluminum (or brass) tubing, say 1 cm in diameter and 5 cm long. Bore a horizontal hole of the same diameter into the ripple tank frame, close to one of the tank's corners, so that drainage may be assisted by tilting the tank towards the corner. The bottom edge of the outlet hole should be at the same level as the top surface of the glass (or just a little below).

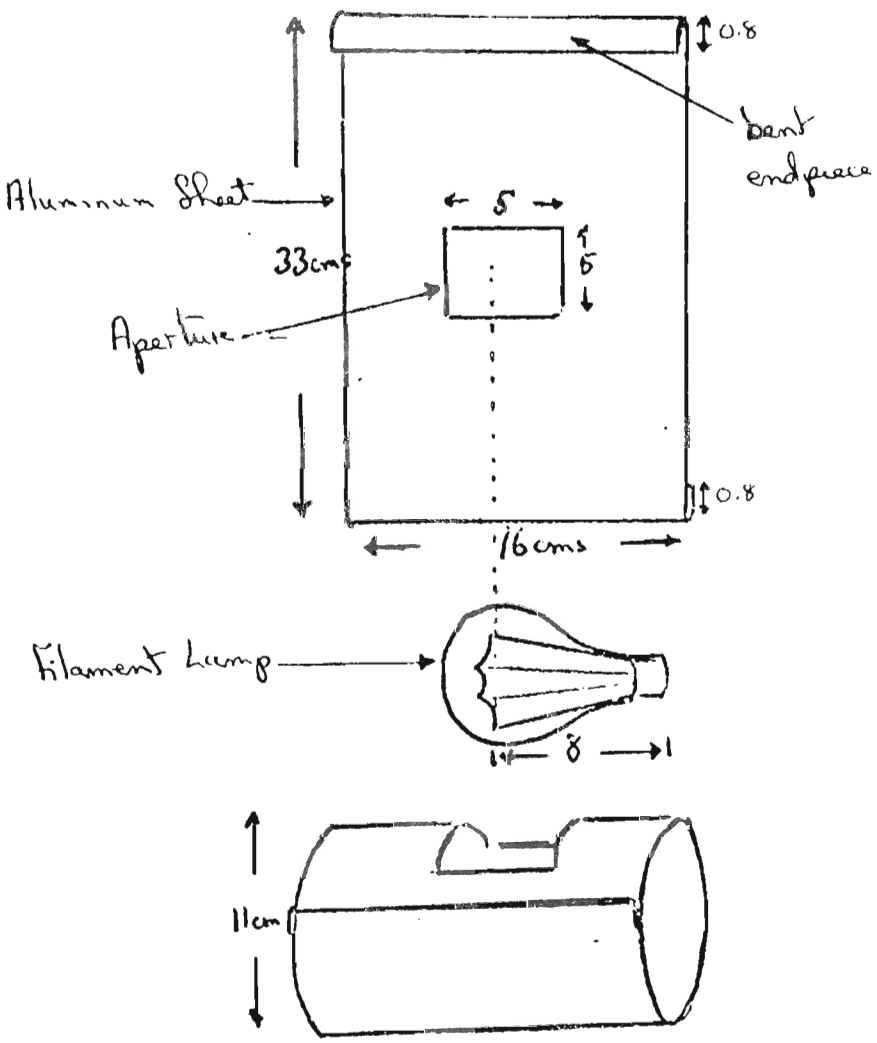
Seal the metal tube into the horizontal hole with a waterproof cement. Bore a hole (0.9 cms diameter) partway into a rubber stopper using an electric drill (not a cork borer). Fit the stopper on the tube, thus controlling the outflow of water.

(4) Legs



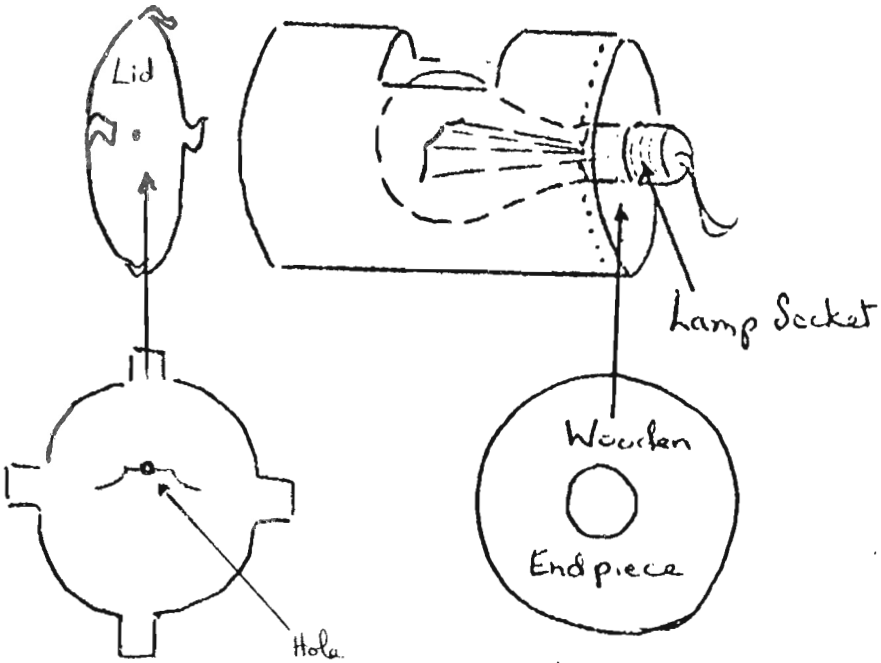
Cut 4 identical legs (60 x 3 x 2 xms) out of wood, and drill and chisel a slot (2 x 0.5 cms) in the top of each to permit adjustment. Make 4 insets (0.3 cms deep) in the frame to hold the legs firmly in a vertical position. Finally, drill a horizontal hole (0.45 cms diameter) through the lower part of the outer frame (that is beneath the level of the glass) at the middle of each inset. Attach each leg to the frame with a bolt (0.45 cms diameter, 3 cms long) passed through the hole in the frame and the slot in the leg. Fasten it with a wingnut.

(5) Lamp Housing



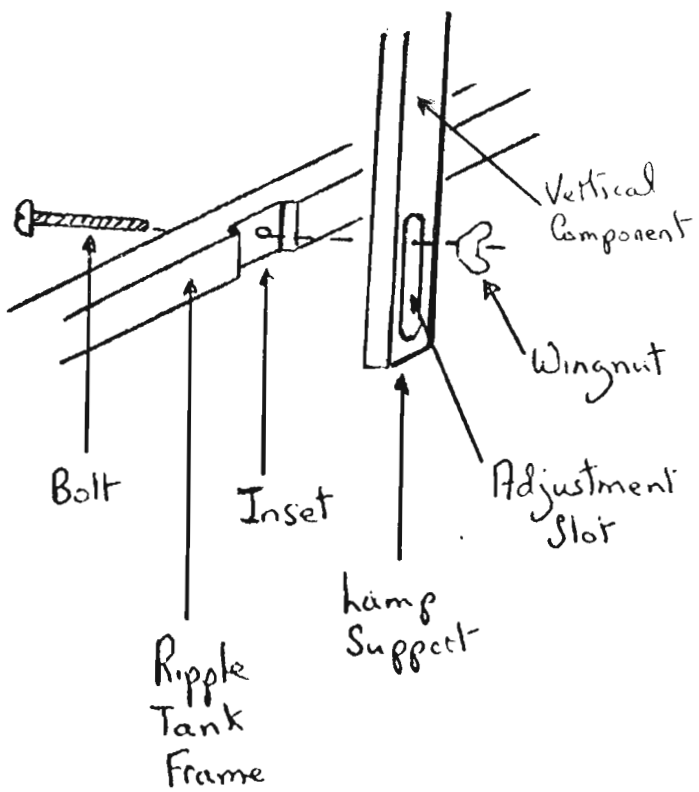
The size of the lamp housing will be dependent on the size of the contained lamp. In this case the lamp utilized was a 220 volt, 100 watt lamp with its filament 8 cms from the socket. Ideally the filament should be a straight line, but a slightly bent filament such as that illustrated will serve the same purpose.

To make the housing for the above lamp take a sheet of aluminum (35 x 16 cms) and cut an aperture (5 x 5 cms) from its center. Roll the sheet into a cylindrical shape, and hold it in position by means of bent end pieces.

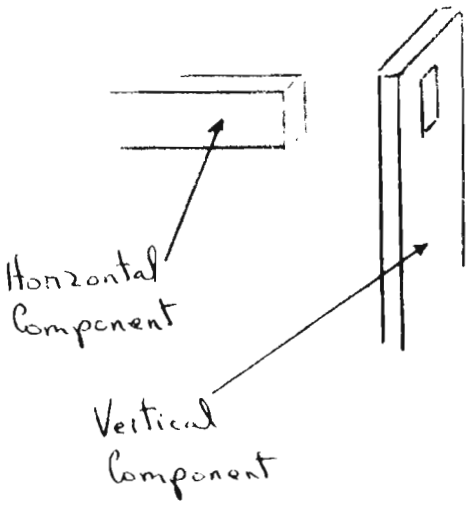


Cut a circular endpiece (11 cms diameter, 0.4 cms thick) from hardboard or plywood and attach it to the base of the container with very small nails. Drill a central hole in the endpiece to facilitate the placement of the lamp and electrical socket. Complete the housing by making a lid out of aluminum sheeting. Drill a small hole (0.2 cms diameter) in the lid, such that it is in line with the filament.

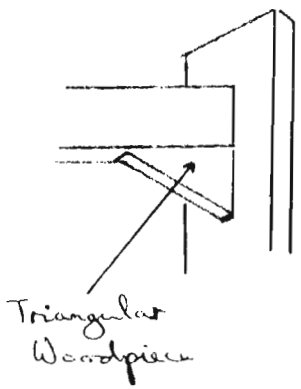
(6) Lamp Support

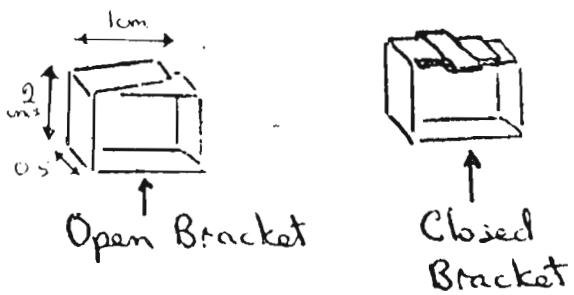


The vertical component of the lamp support is made, and attached to the ripple tank, in very much the same way as the legs. The vertical component itself should be 65 x 3 x 2 cms with a slot 7 x 0.5 cms cut near to its bottom end to permit adjustment.

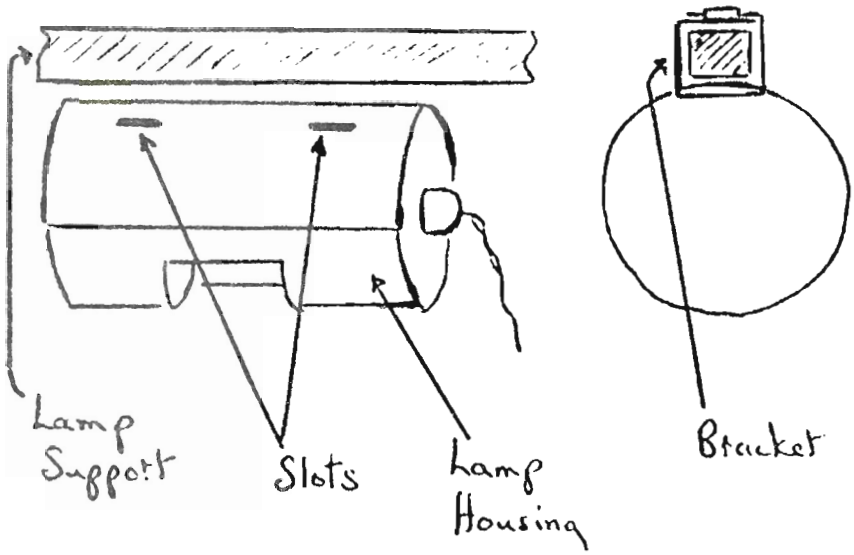


Cut a rectangular hole (2 x 1 cms) in the top of the vertical component to take the horizontal component (48 x 2 x 1 cms). Fasten the two firmly together with wood cement. A triangular piece of wood may be glued between the two components to make a stronger junction.

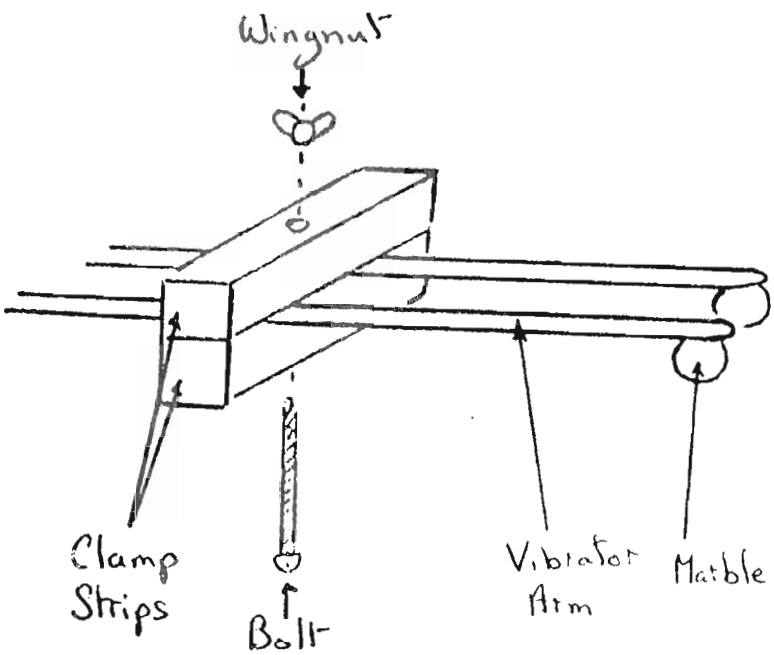


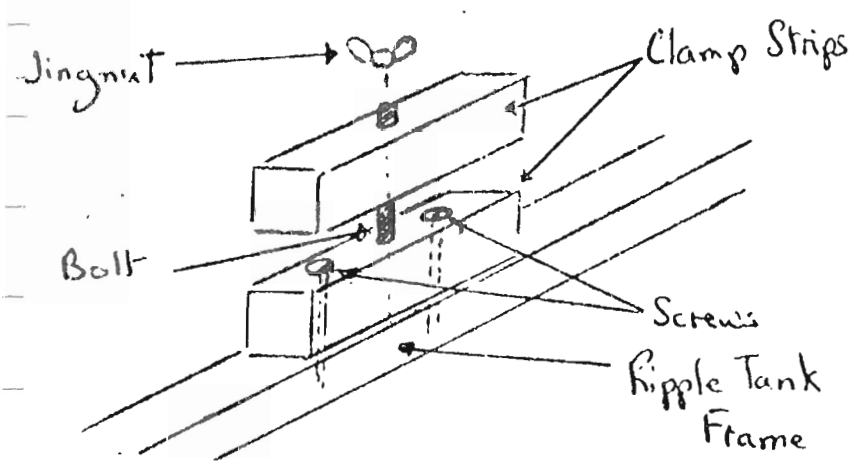


In order to attach the lamp housing to the horizontal component of the support make two brackets from steel strips (packing case bands) as illustrated. Cut 4 horizontal slots in the upper part of the lamp housing and pass the steel strips through. Fasten the loose ends of the brackets together with a folded piece of aluminum or packing case steel. Then slide the brackets over the horizontal component of the lamp support.



(7) Vibrators



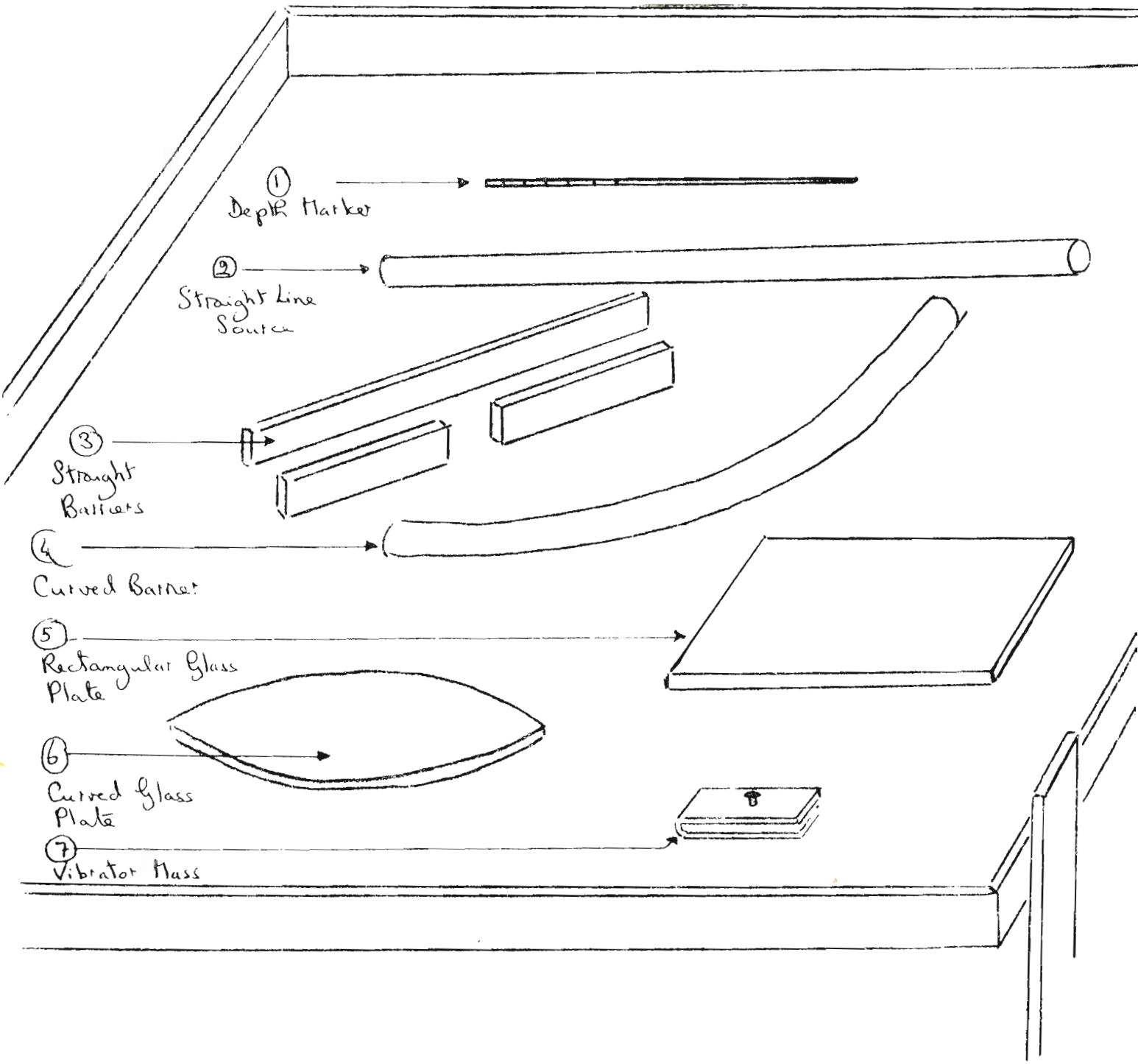


Obtain two steel strips (30 x 1 x 0.1 cms), or stiff coathanger wire, to serve as the arms of the vibrator. Attach a glass sphere (diameter approximately 1.5 cms) to the end of each arm using epoxy resin.

Make the vibrator clamp from two strips of wood (each 7 x 2 x 1 cms).

Drill a hole (0.45 cms diameter) through both to take a bolt. Insert the bolt (diameter 0.45 cms, length 2.5 cms) through the lower strip, and then attach the strip to the frame with two screws. Sit the top strip on top of the first, and fasten it in position with the bolt and wingnut. The vibrator arms may now be clamped firmly between the strips of the clamp, being held at the middle of the arms. This insures the maximum possible period of vibration.

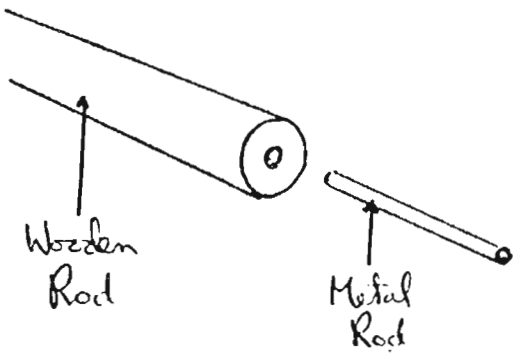
3.10/02 Ripple Tank Accessories



(1) Depth Marker

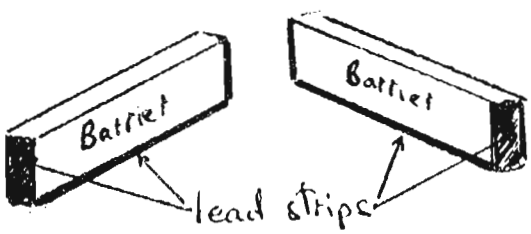
Mark off the end of a 10 cm length of wire in half centimeter intervals (0-2 cms). This is used to determine the depth of the water at the 4 corners of the ripple tank, and makes the levelling of the tank simpler.

(2) Straight Line Source



Cut a 40 cm length of a wooden rod (approximately 2 cms diameter). Bore holes into both ends and insert long nails (or metal rods) to prevent the rod from floating around in the ripple tank.

(3) Straight Barriers



Make the barriers out of wood. The following size barriers are desirable:

1 Barrier	40 x 2.5 x 1 cm
2 Barriers:	15 x 2.5 x 1 cm
2 Barriers:	10 x 2.5 x 1 cm.
1 Barrier:	5 x 2.5 x 1 cm

Prevent the barriers from floating by nailing thin strips of lead along the sides and base.

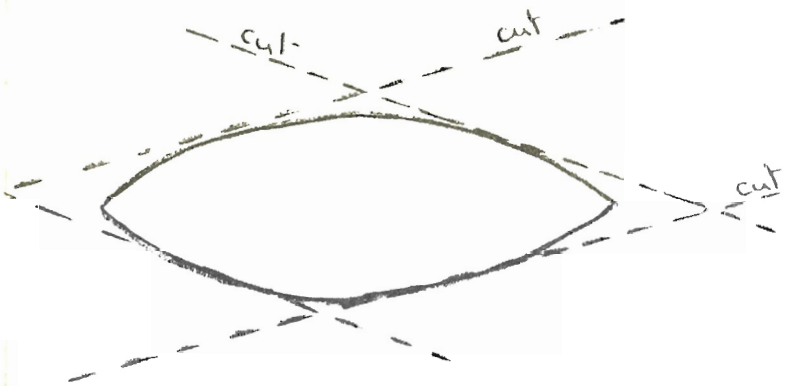
(4) Curved Barrier

Cut about 55 cms off a smooth surfaced hose pipe approximately 2 cms diameter. The pipe may be curved into any desired arc.

(5) Rectangular Plate

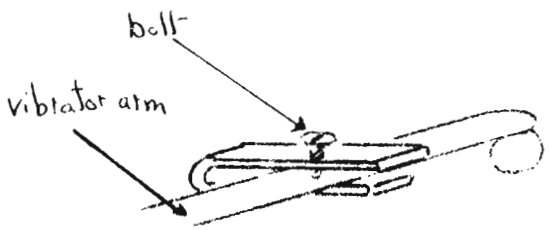
Take a sheet of glass (0.4 cms thick) and mark out two sections (each 25 x 15 x 0.4 cms) with a glass cutter. Break the glass along the marks by hand. The two sheets may be set one on top of the other in water, thus creating a plate of thickness 0.8 cms.

(6) Curved Glass Plate



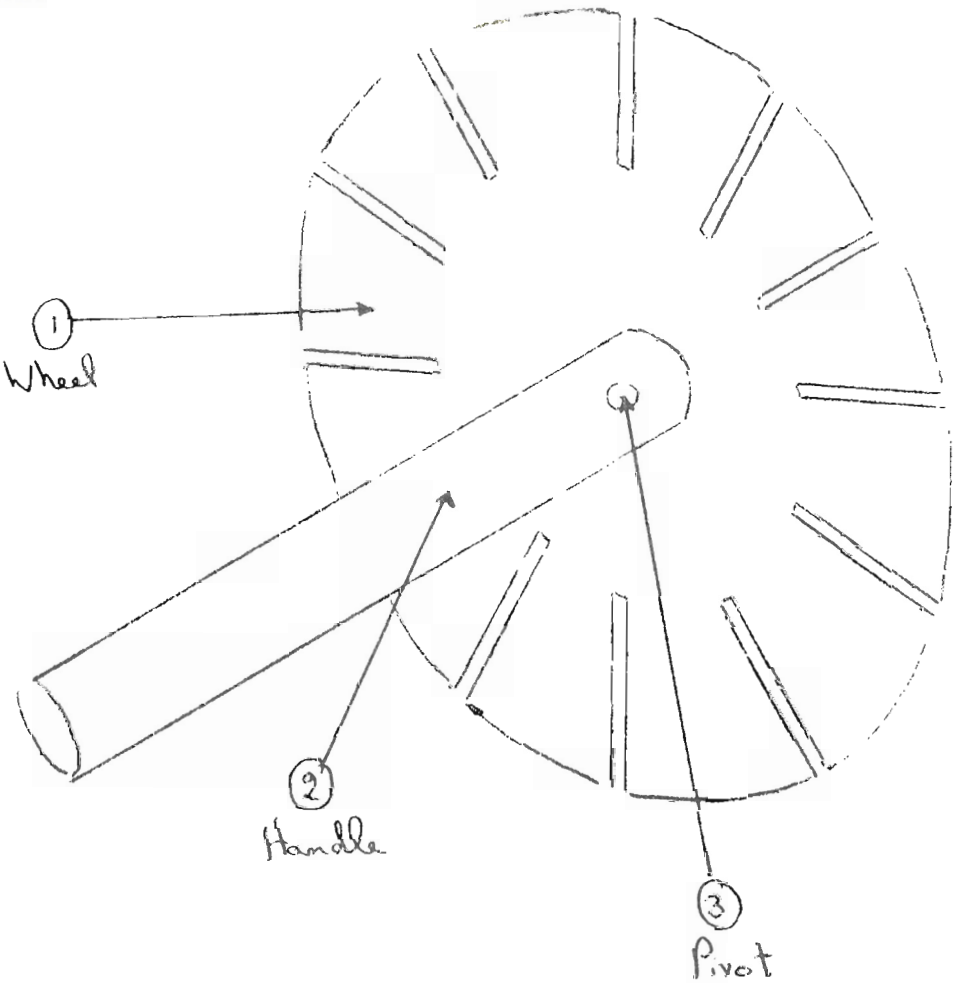
Two curved glass plates (0.4 cms thick) may be made by cutting along the lines indicated. Smooth off the edges with a sandstone. The two plates may be used one on top of the other in the ripple tank making a single plate of thickness 0.8 cms. Equally well the plate may be made from a sheet of plastic (1 cm thick). Simply use a hacksaw to cut along the lines indicated, smoothing off jagged edges with sandpaper.

(7) Vibrator Mass

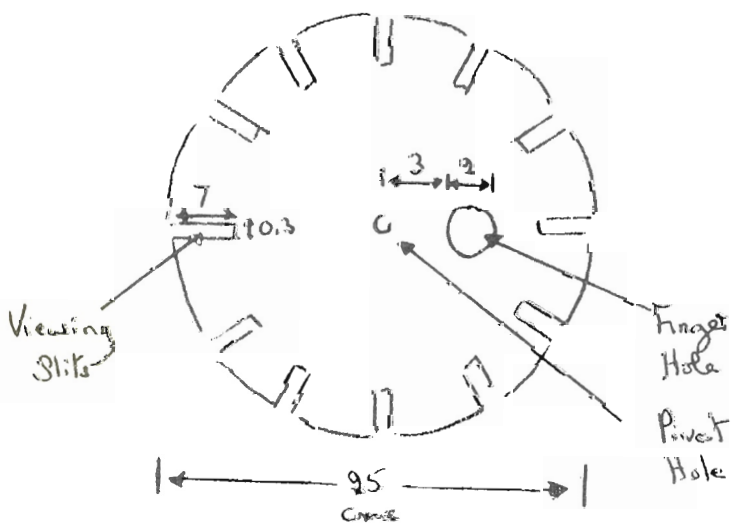


Cut a soft iron bar to the approximate dimensions of 11 x 2 x 0.3 cms, adjusting the size so that the bar weighs approximately 50 gms. Place the bar in a strong clamp, and use a hammer to bend it in half so that it becomes two parallel bars about 0.3 cms apart. Drill a hole (0.2 cms diameter) in the middle of the top bar, and make a thread (0.2 cms diameter) in the hole. A 1 cm long bolt screwed into the hole will make it possible to clamp the bar onto the ripple tank's vibrator arm.

3.10/03 Stroboscope



(1) Wheel

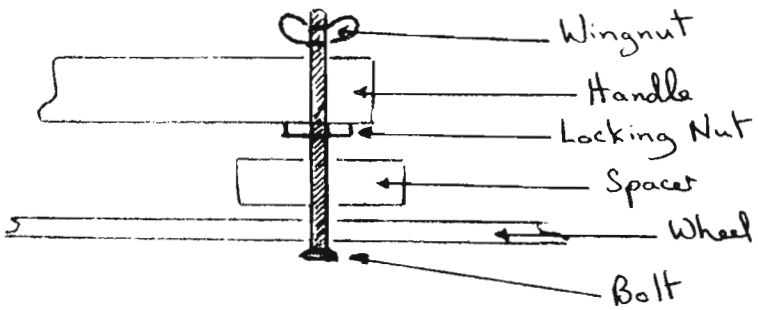


Cut the stroboscope wheel from a piece of hardboard about 0.3 cms thick. Make 12 equally spaced slits in the perimeter of the wheel. Drill a finger hole at a distance of 3 cms from the center of the wheel, and a pivot hole (0.5 cms diameter) at the center of the wheel.

(2) Handle

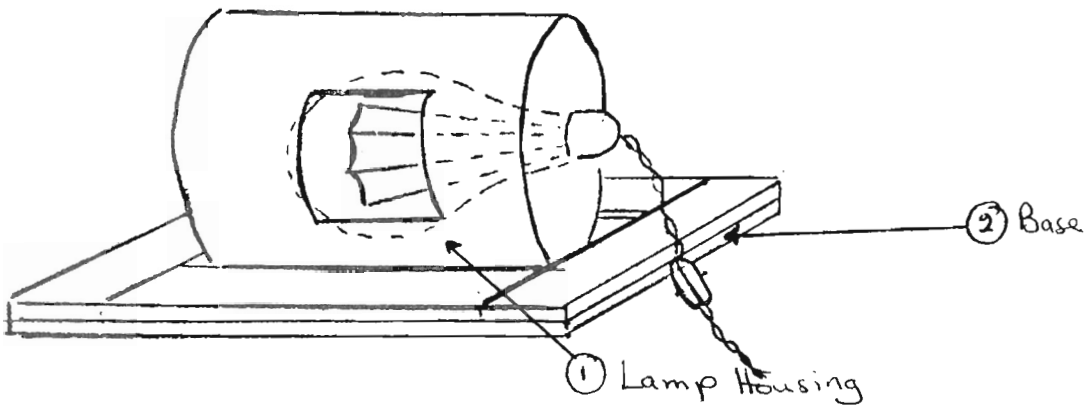
The handle is simply a wooden dowel (2 cms diameter, 25 cms long). Drill a hole (0.45 cms diameter) through one end of the handle to take the pivot bolt.

(3) Pivot



Obtain a bolt (0.45 cm diameter, 4.5 cms long) to serve as the pivot for the wheel. Insert this through the wheel, a spacer (diameter 3 cms, width 1.5 cms) a locking nut and the handle. Use the locking nut and a wingnut to hold the handle in a fixed position on the pivot.

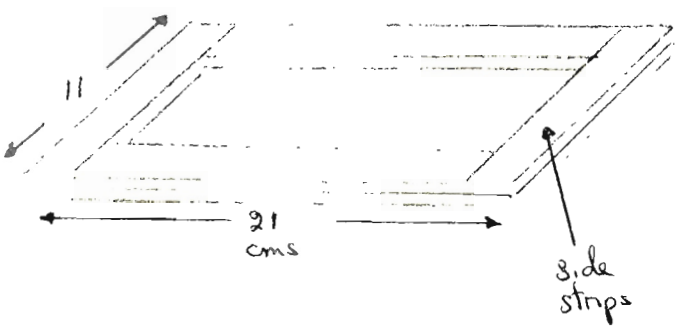
4.10/01 Light Source with Base



(1) Lamp Housing

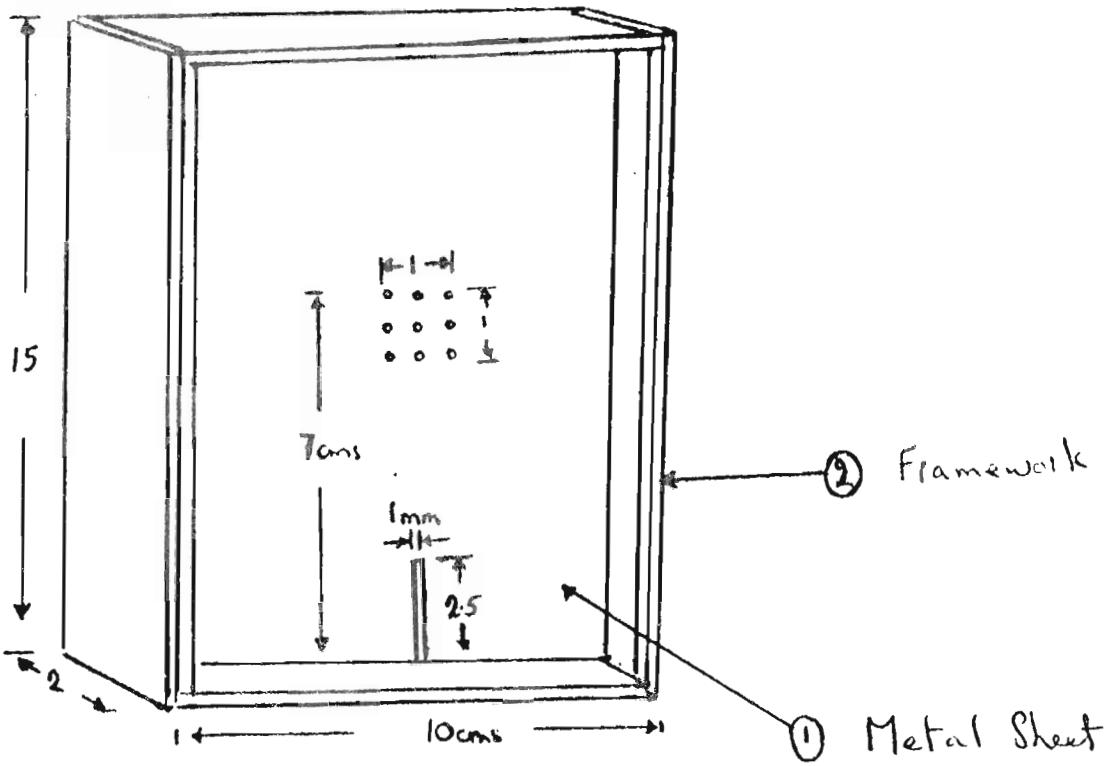
This is precisely the same lamp housing as that designed for the ripple tank (3.10/01). All that is added is a base.

(2) Base

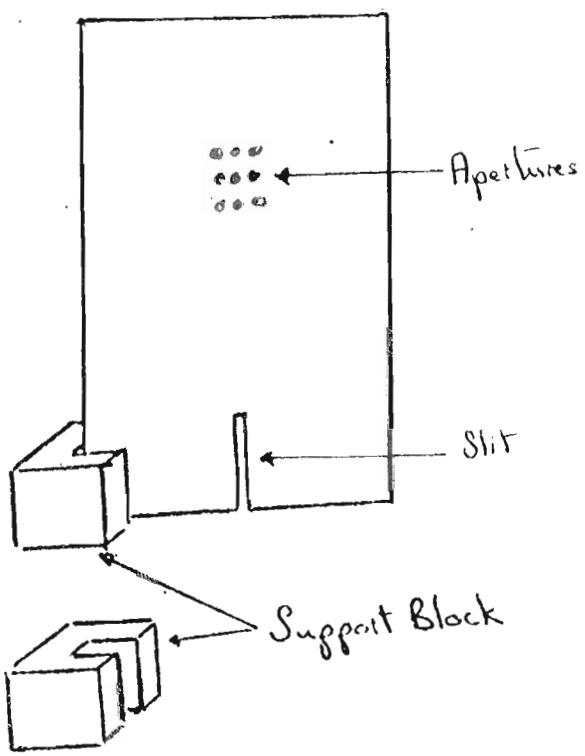


Cut the base from a piece of plywood (21 x 11 x 0.5 cms). Cut 4 side strips (2.5 cms wide, 1 cm deep), two of which will be 11 cms long while the other two will be 16 cms long. Make sure that they will hold the lamp housing firm, and then nail into position.

4.10/02 Slit/Aperture Combination

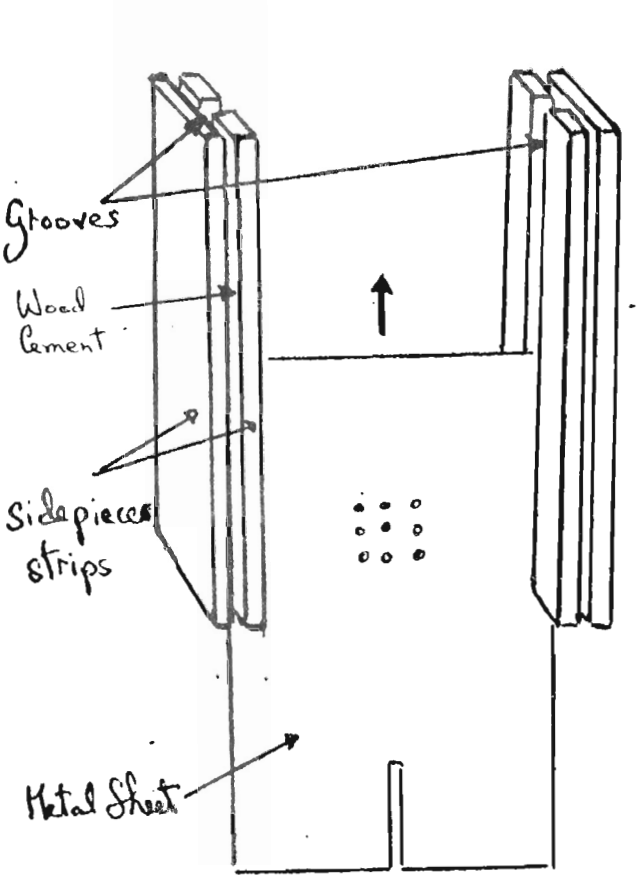


(1) Metal Sheet

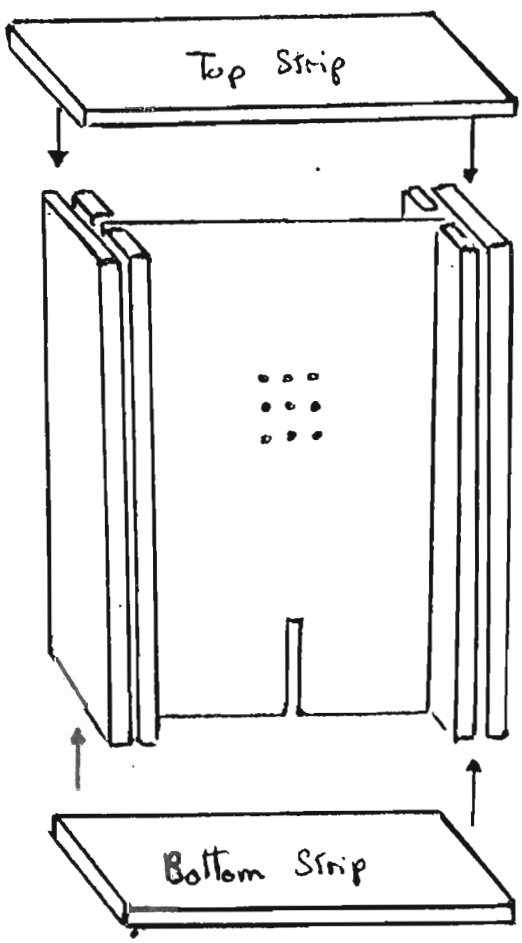


Cut the slit (0.1 cms width) and apertures (0.1 cms diameter) in any suitable thin sheeting (metal, bakelite, cardboard) so long as the slit and apertures have clean cut edges. If the material used is relatively rigid, a small wooden block will provide adequate support. If the material tends to flex under its own weight a framework, such as that indicated below, will be required for support.

(2) Framework

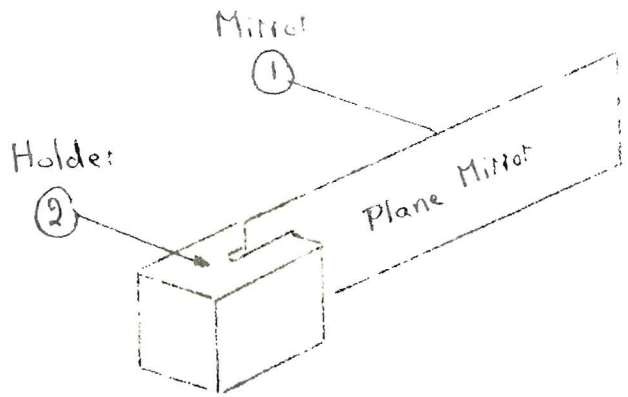


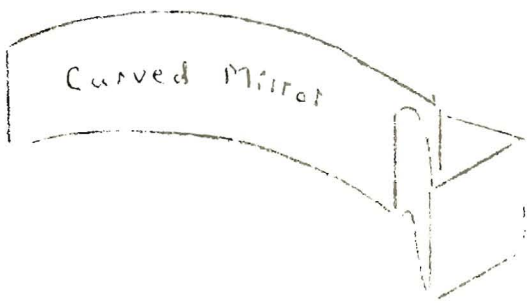
Make each sidepiece of the frame from three strips of wood, so as to create a thin groove (as illustrated) between the two inner strips. Then slide the metal sheet between the two parallel grooves, finally fitting the top and bottom strips of the frame with wood cement, or small nails.



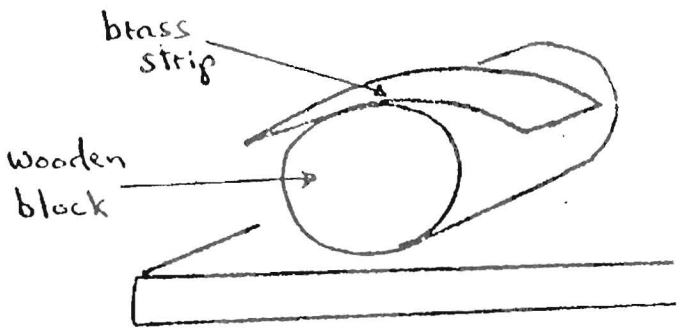
The thickness of the bottom strip should not be much more than 0.5 cms, as there is a tendency for this strip to cut off a desirable portion of any light path.

4.10/03 Mirrors and Electroplating





(1) Mirror



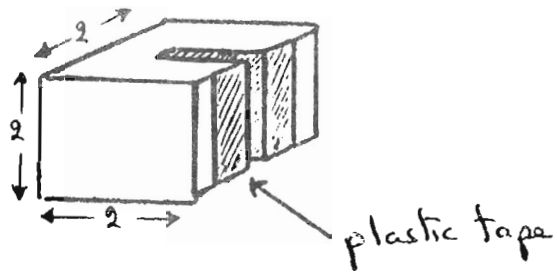
Cut a sheet of brass (10 x 2.5 x 0.1 cms) on a metal guillotine (to be found in your nearest metalwork shop). If the metal sheet is cut with bench sheers some distortion is almost certain to result, thus lowering the quality of the mirror. If the mirror is to be curved, bend it over a smooth, curved, wooden block until the mirror becomes the arc of a circle of radius 8.5 cms.

Polish the metal strips first with coarse carborundum paper, and then with successively finer and finer grades, taking care at each polishing to remove the deeper marks of the previous polishing.

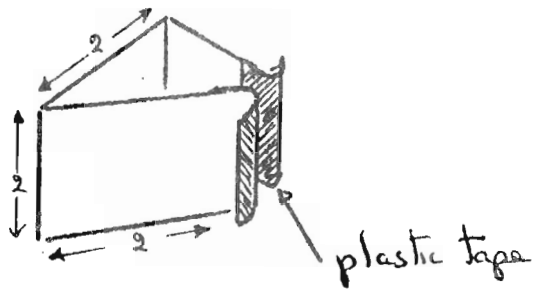
Obtain a mirror finish by polishing the surface with a soft cloth and metal polish.

(2) Holder

Cut a slot (0.2 cms wide) in a wooden block (2 x 2 x 2 cms). Line the slot with plastic tape to prevent the wood from scratching the surface of the mirror to be held.



Alternatively, take a packing case band (approximately 7 x 2 cms) and bend it into a triangular shape. Curve the endpieces and cover them with plastic tape to protect the mirror surface.



Note:

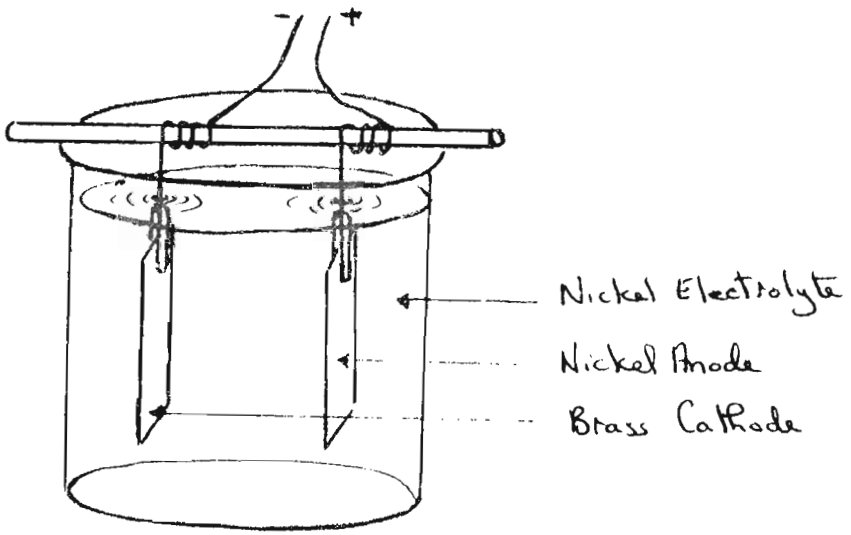
Brass mirrors must be cleaned with metal polish before each usage. This process may be eliminated if the metal surface is electroplated. The procedure to be followed is described below.

(i) Procure a plastic, or glass, container about 15 cms deep and 10 cms in diameter, and fill it with a nickel solution (e.g., Gleamax and Levelbrite).

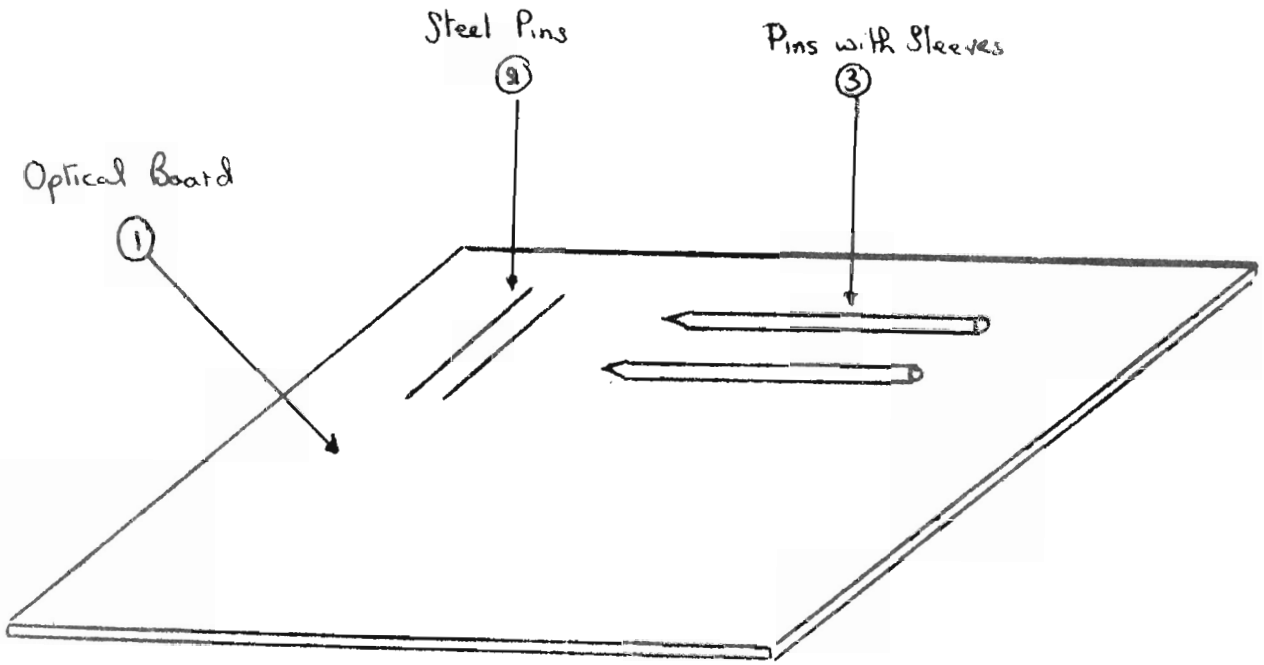
(ii) Wash the polished brass mirror in caustic soda (soap) to remove grease and rinse with clean water. Grip the brass mirror in a crocodile clip, attached to an electrical lead, and suspend the brass mirror in the nickel solution. The mirror may be held in position by wrapping the electrical lead (by which it is suspended) around a wooden dowel bridging the container.

(iii) Suspend a nickel plate in a similar fashion from a second electrical lead. We now have an anode (nickel plate), a cathode (brass mirror) and an electrolyte (nickel solution).

(iv) Connect the anode to the positive terminal and the cathode to the negative terminal of a 6 volt battery, and pass a current through the nickel solution for 15 to 20 minutes. The quality of the final surface will depend primarily on the quality of the initial polished surface, prior to electroplating.



4.10/04 Optical Board with Pins



(1) Optical Board

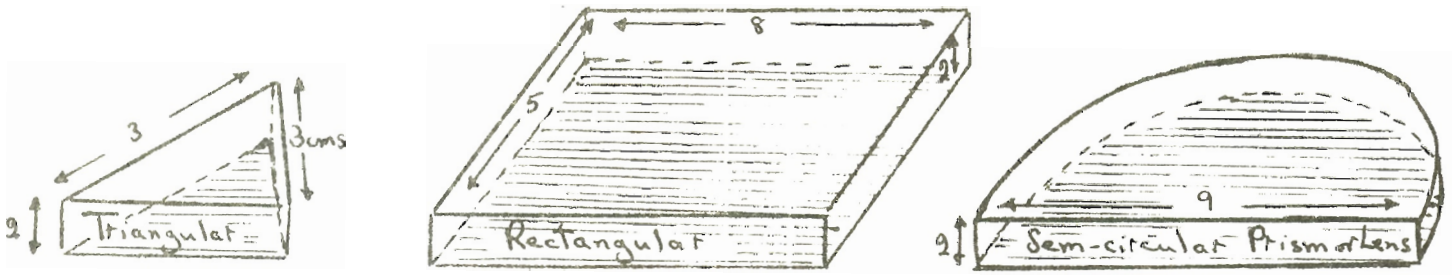
This is simply a piece of hardboard about 40 x 40 cms into which pins can be readily stuck. Normally a plain sheet of paper will be placed on top of the hardboard to facilitate the recording of experimental observations. The Refraction Model Apparatus is such a piece of hardboard (40 x 40 cms).

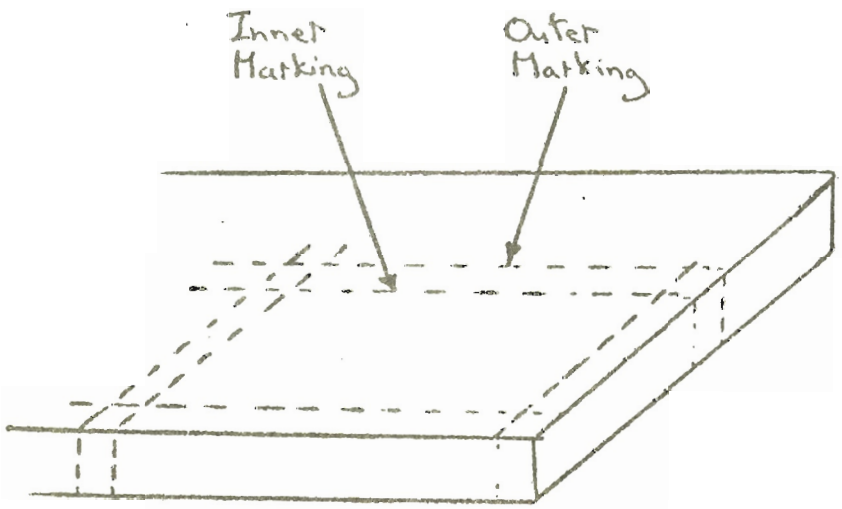
(2) Steel Pins

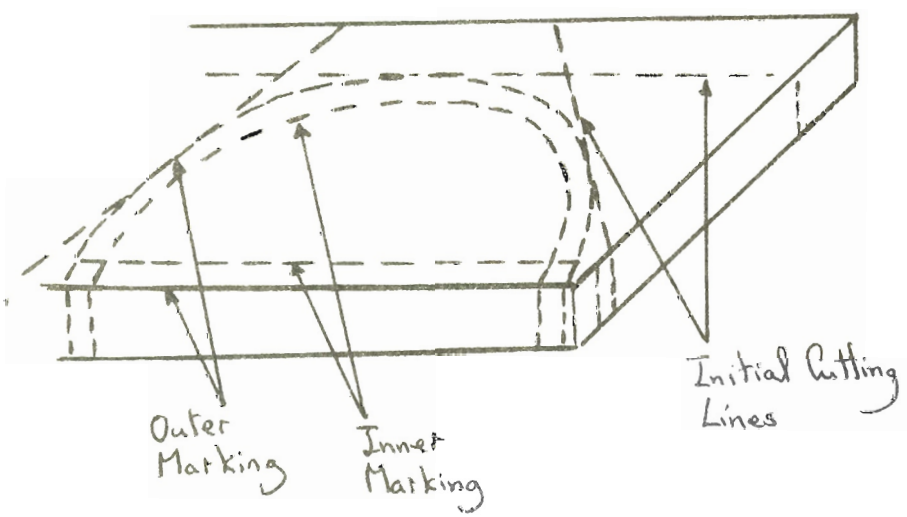
Make the pins (7 cms long, 0.1 cm diameter) from any appropriate steel (e.g., cycle spokes) simply by cutting off the desired length, and sharpening one end on a file.

Cut a pencil to a length of 6.5 cms. Remove the pencil lead with the help of a steel pin. Coat the steel pin with epoxy resin, and slide it into the space originally occupied by the lead, so that, instead of the pencil lead, a steel pin protrudes from the end. Cover the sleeve with a white coat of paint.

4.10/05 Optical Prisms and Lenses



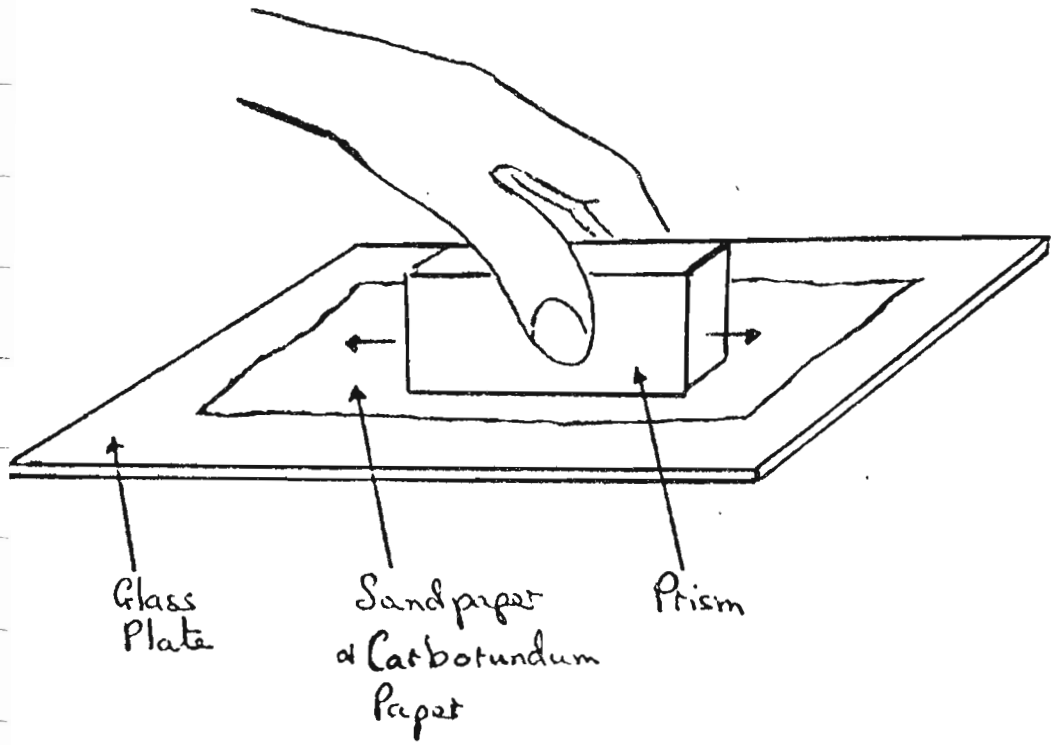




All the above prisms are made from plastic (acrylic) sheets about 2 cms thick by precisely the same process indicated below.

Take a sheet of plastic, and mark out the shape of the desired prism with a sharp point. Draw a parallel set of lines about 0.5 cms outside the initial marking.

Using a fine toothed saw carefully cut the plastic down to the outer markings. The cut produced will have very jagged edges, the plastic showing a tendency to chip. This is normal, and should cause no concern.



The next step is to remove the rough edges from the prism, reducing its size to that of the inner markings. For this purpose place a coarse sheet of carborundum paper on top of a smooth surface (e.g., a strong glass sheet). Then smooth down the surfaces of the prism by rubbing the latter on the carborundum surface.

Repeat the process with successively finer and finer grades of carborundum paper, taking care at each rubbing to remove the deeper marks of the previous rubbing.

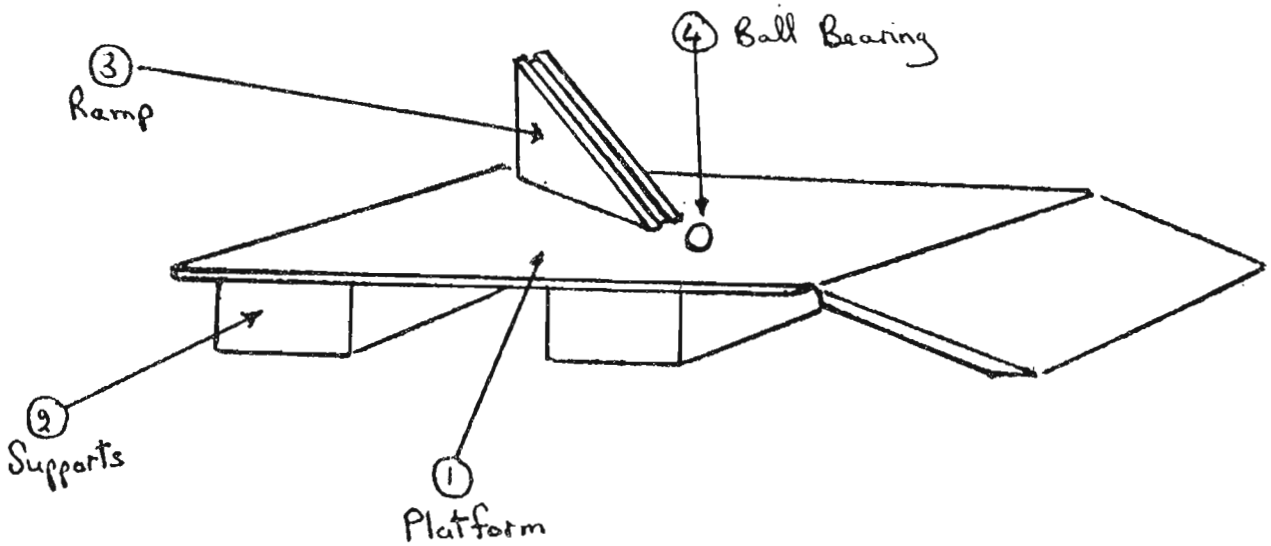
Finally, replace the carborundum paper by a sheet of plain paper. Drop a little metal polish on the paper, and repeat the rubbing process. The surface produced will be highly polished.

The rubbing and polishing process is repeated with all the surfaces except that surface which will normally be in contact with the table top during experimentation. This surface is smoothed with carborundum paper, but not metal polish, thus leaving the surface sufficiently rough to scatter light.

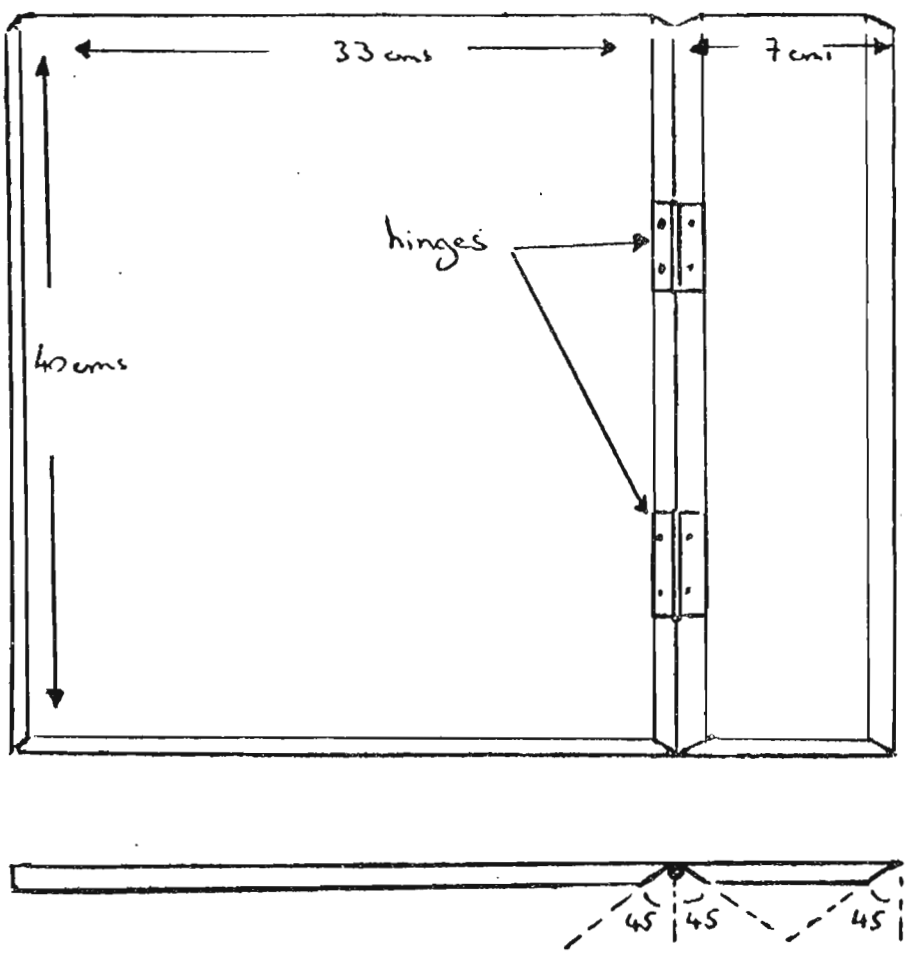
Note:

Plastic is not as hard as glass, and is therefore more easily scratched and damaged. From time to time it is therefore necessary to repolish the surfaces with metal polish, as described above.

4.10/06 Refraction Model Apparatus



(1) Platform



Take a sheet of hardboard or plywood measuring 40 x 40 x 0.5 cms. Cut a 7 cm strip from one side, and shape the newly cut edges back at an angle of 45 degrees as illustrated. Reattach the 7 cm strip to the platform with very small hinges avoiding the creation of a gap between the strip and main platform. Shape the free edge of the 7 cm strip to an angle of 45 degrees. This shaping insures good contact between the strip and the table.

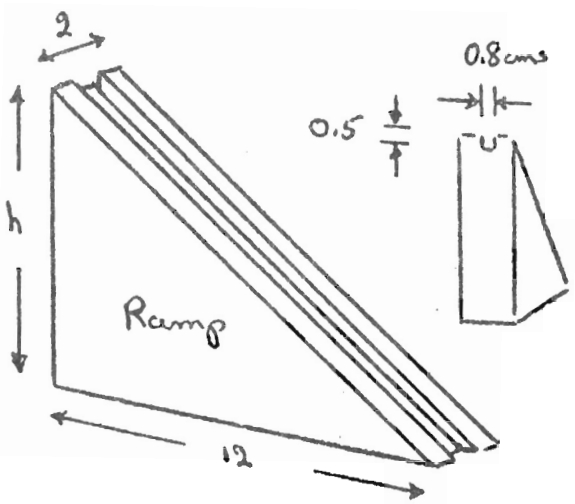
(2) Supports

Books, or blocks of wood, may be used to elevate the platform to different heights above the table top (say to heights of 2 and 4 cms).

(3) Ramp

Cut two triangular shapes out of a piece of wood about 2 cms thick. The height of one triangular shape will be 5 cms and the other 3 cms, while both will have a base 12 cms long.

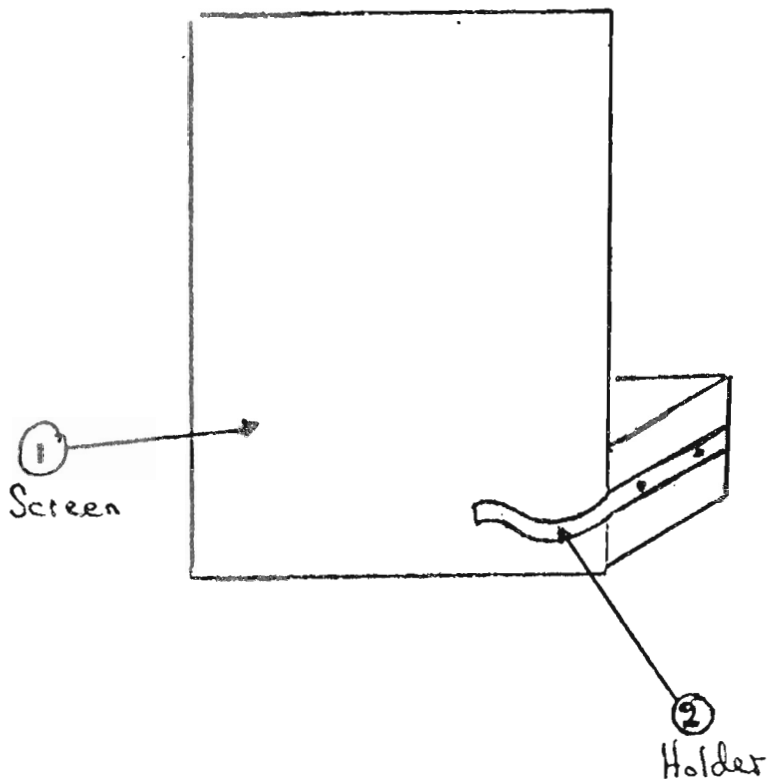
The groove is best cut with the help of a saw.



(4) Ball Bearing

A ball bearing (2.5 cms diameter) is required for use with the apparatus.

4.10/07 Screen with Holder

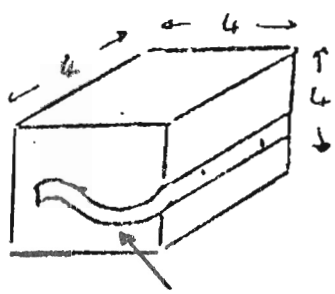


(1) Screen

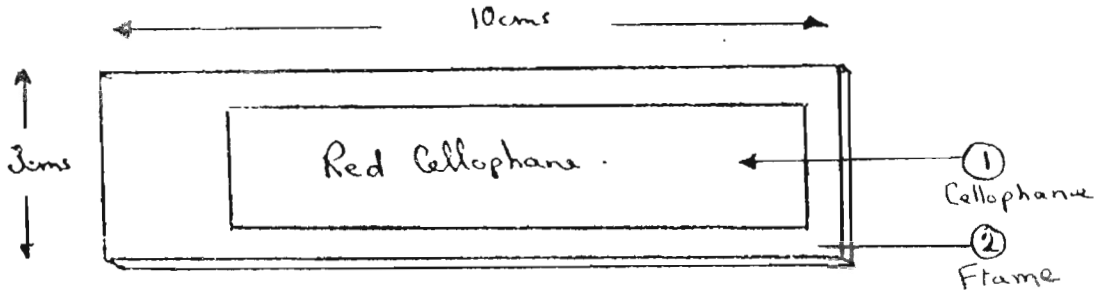
Make the screen from a stiff piece of cardboard, say 25 x 15 cms. It is very convenient to have a front white surface and a rear black surface. This may be achieved by sticking appropriate sheets of paper on the two surfaces.

(2) Holder

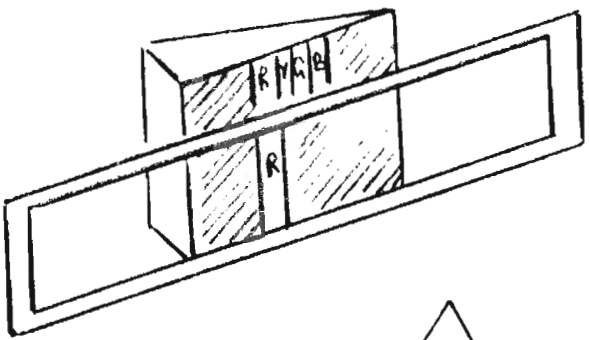
Bend a length (8 cms) of packing case steel as shown and nail it to the side of a wooden block (4 x 4 x 4 cms)



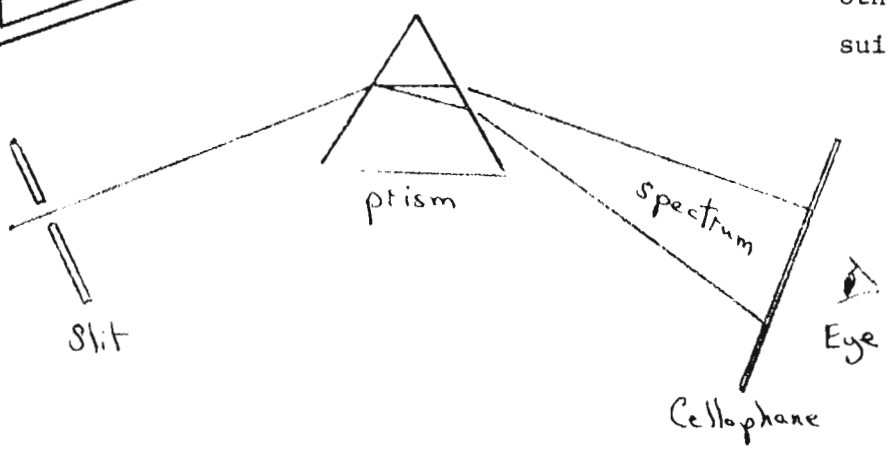
4.10/08 Filter (Red)



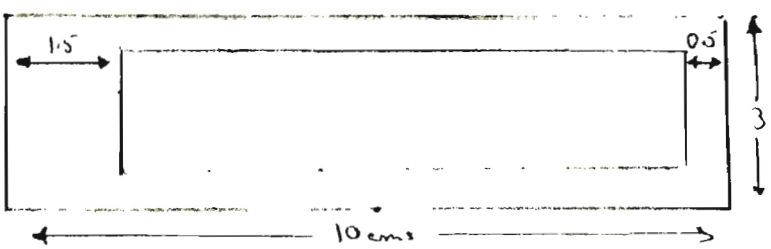
(1) Cellophane



Test different strips of red cellophane for suitability by noting what parts of a spectrum can be seen through the cellophane. The cellophane cutting out almost all colors other than red will be most suitable.

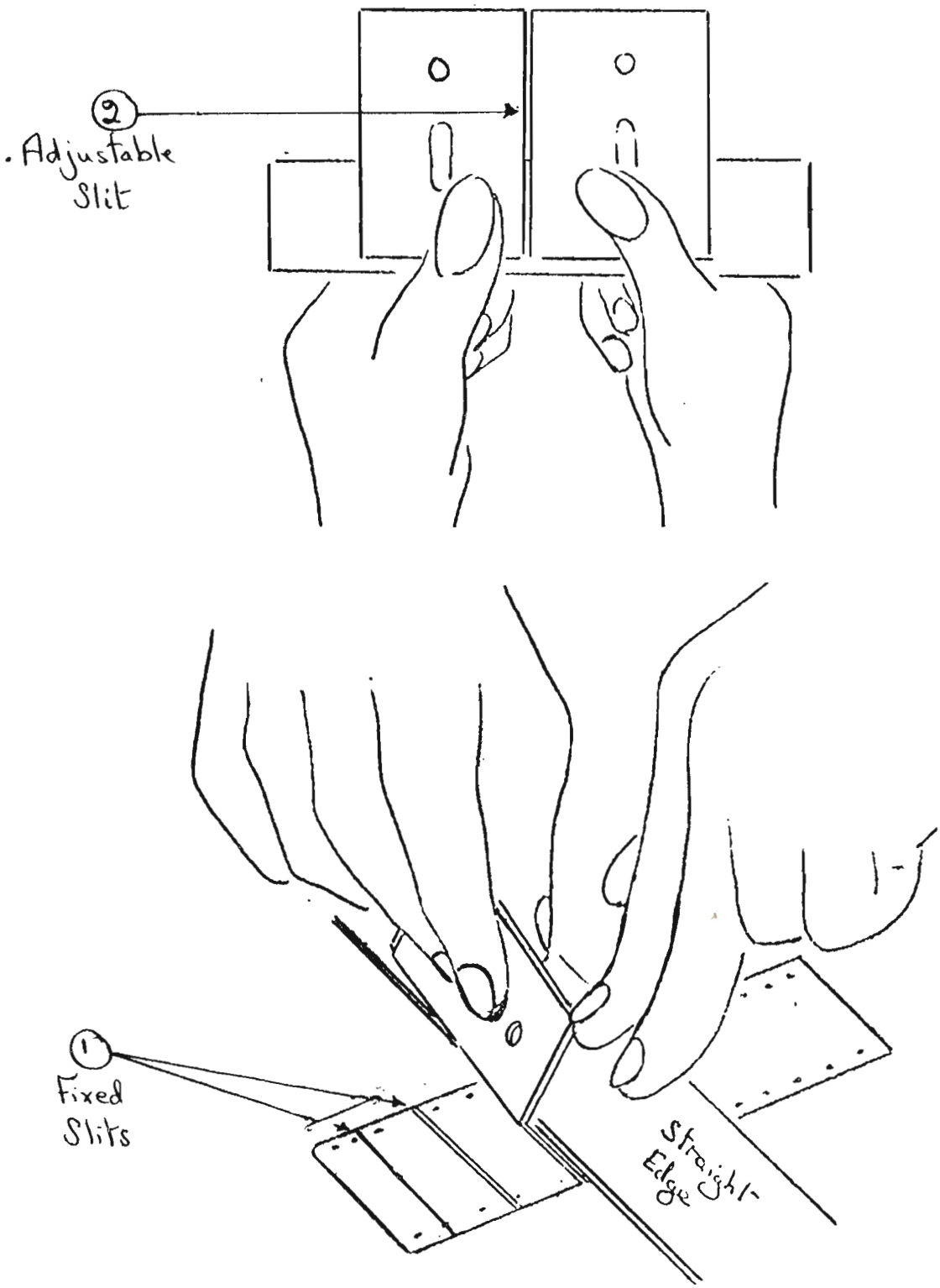


(2) Frame



Cut two pieces of cardboard to the shape indicated, and stick (or clip) a suitable piece of red cellophane between the two pieces.

4.20/01 Simple Diffraction Slits



(1) Fixed Slits

Take an exposed strip of film (or a slide coated with colloidal graphite) and draw a straight line across it using a razor and a straight edge as a marker. The width of the slit may be increased, if desired, by drawing the razor over the same approximate line two or three times.

A double slit may be made in an almost identical way. Simply hold two razors face to face instead of one, and draw the line across the film with the two razor blades pressed closely together. The space between the slits may be increased, if desired, by holding the blades at an angle to the vertical as the double line is drawn against the straight edge.

(2) Adjustable Slit

Hold two razors against a metal strip so that the edges of the blades are almost touching and are parallel to one another.

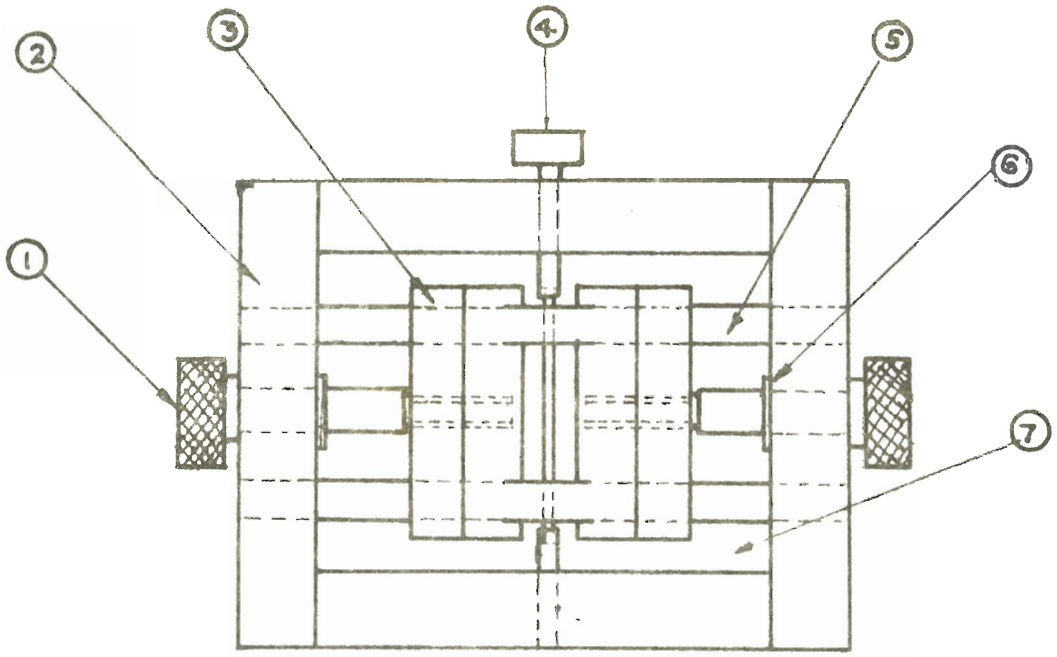
The combination may readily be converted to an adjustable double slit by using epoxy resin to attach a needle (3 cms long, 0. 1 cm diameter) at right angles

to the metal strip, and then holding the two blades (against the strip) as close to the needle as possible.

Note:

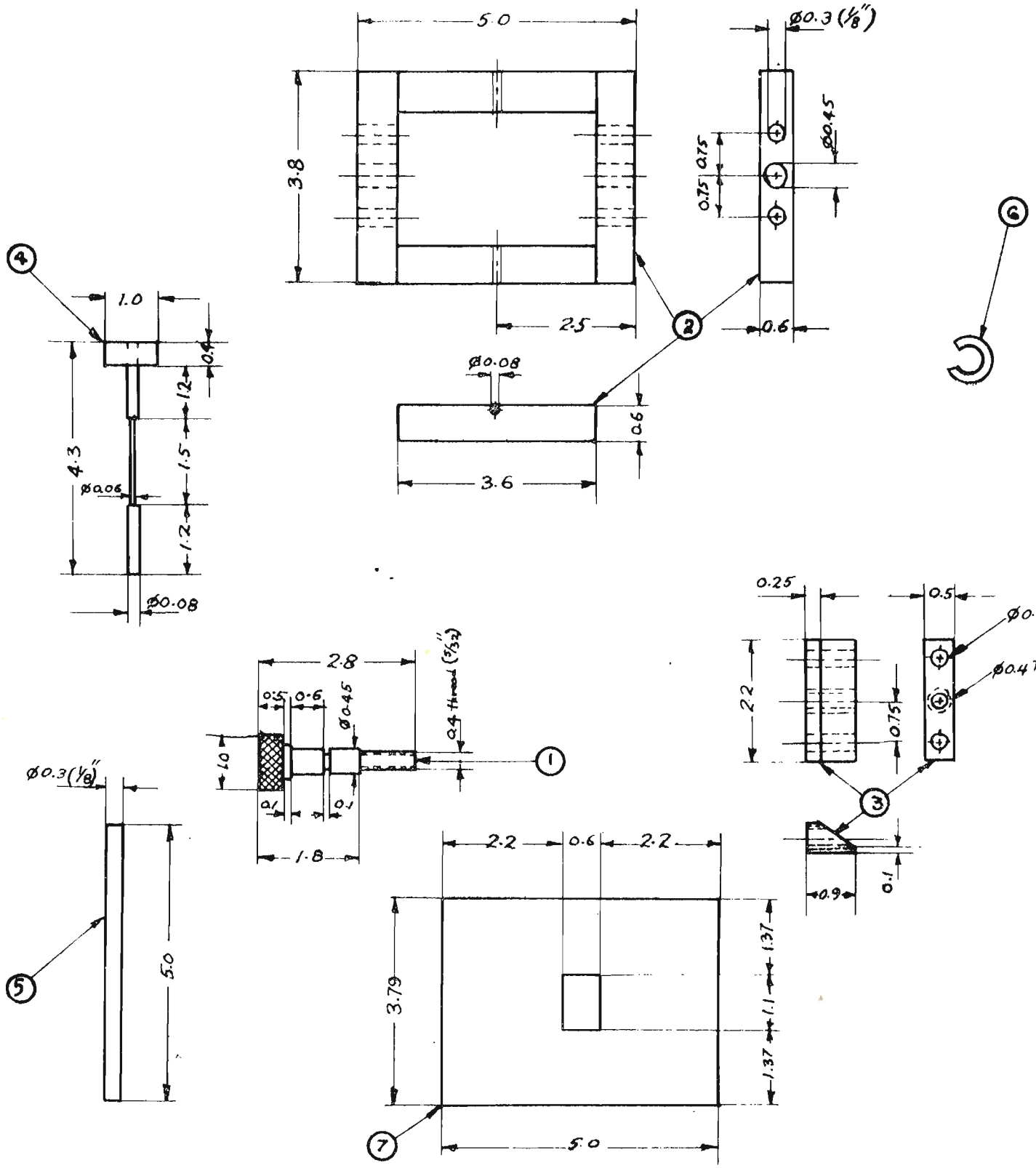
A somewhat more sophisticated adjustable slit, based on the same principle as the above item, is included next. However, it is anticipated that this will only be produced by those possessing particular technical skills.

4.20/02 Adjustable Diffraction Slit



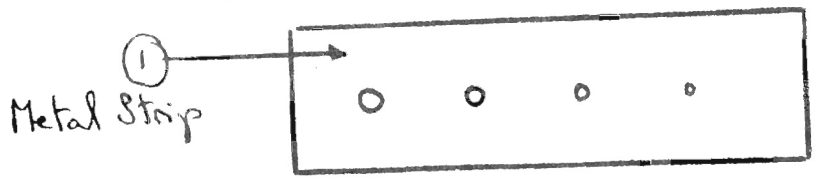
ADJUSTABLE SLIT

PART NO.	DESCRIPTION	DIMENSIONS	QUANTITY
1	ADJUSTABLE SCREW - BRASS	1·0x2·8x0·4	2
2	FRAME - WOOD	5·0x3·8x0·7	1
3	SLIDING PLATE - BRASS	0·6x0·7x2·2	2
4	NEEDLE (WITH HEAD)	1·0x0·08x4·2	1
5	STEEL GUIDE	ϕ0·3x5·0	2
6	LOCK WASHER	0·1x0·4	2
7	COVER PLATE - ALUMINIUM	0·15x3·7x5·0	2



PART NO.	INTERFERENCE SLIT PARTS 1-2-3-4-5-6-7	SCALE
1	ADJUSTABLE SCREW - BRASS	1:1
2	FRAME-WOOD	1:1
3	SLIDING PLATE - BRASS	1:1
4	NEEDLE - STEEL ROD	1:1
5	STEEL GUIDE	1:2
6	LOCK WASHER	1:1
7	COVER PLATE - ALUMINIUM	1:1

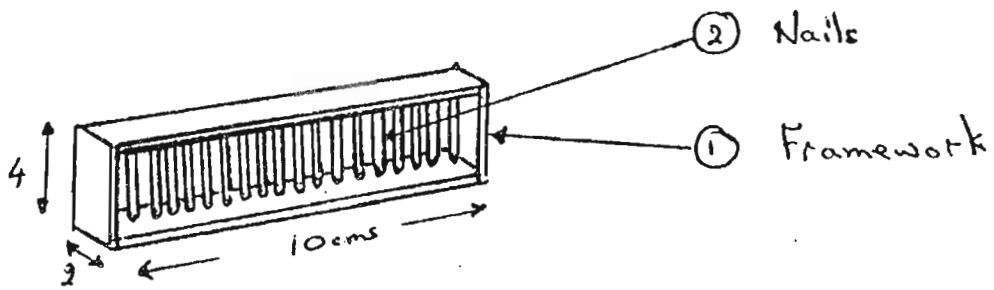
4.20/03 Simple Diffraction Holes



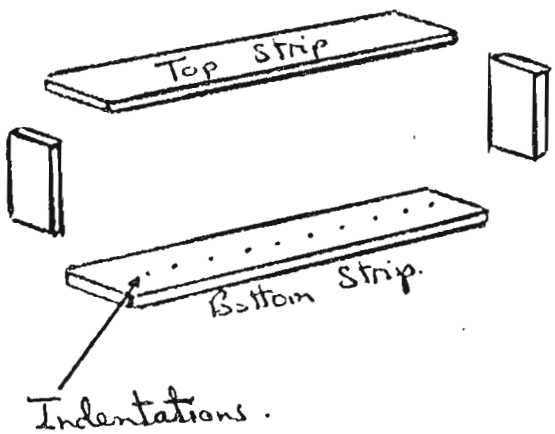
(1) Metal Strip

Take a strip of aluminum (10 x 2.5 x 0.1 cms) and drill 4 holes (diameters approximately 0.1, 0.08, 0.05, and 0.02 cms) in it at regular intervals.

4.30/01 Multiple Slit

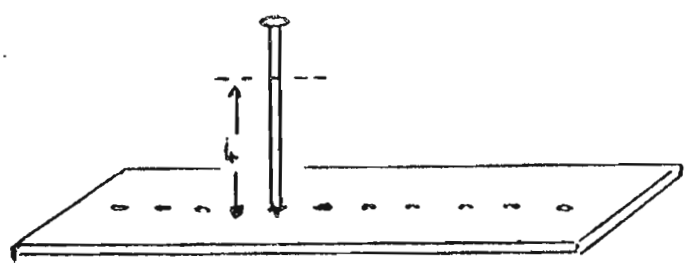


(1) Framework



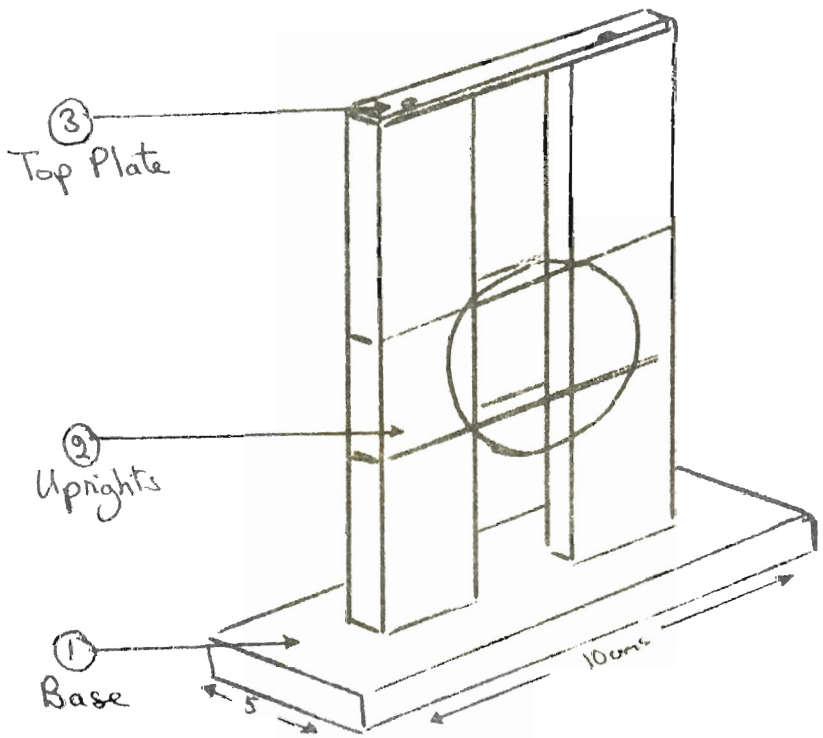
Take 4 strips of wood (0.5 cms thick) to make the basic framework. Make regular identations down the middle of the top and bottom strips of the framework, the indentations being 0.4 cms apart.

(2) Nails



Take a handful of nails (abou 0.2 cms in diameter) and cut off the top ends to produce a uniform set of nails, each 4 cms long. Tap the nails into the bottom strip, positioning them in the indentations. Then press the upper strip onto the upright nails, using the indentations on the upper strip for guidance in positioning the nails parallel to one another. Finally, attach the side pieces of the framework using very small nails or wood cement.

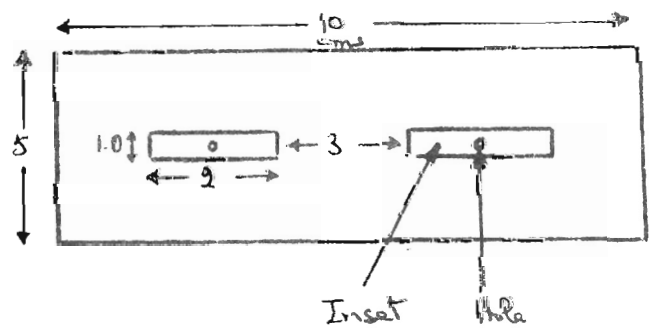
02 Lens Holder



(1) Base

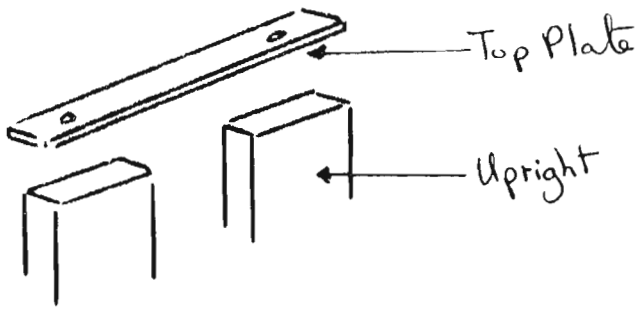
Cut the base out of wood 1 cm thick. Make two insets (0.5 cms deep and 3 cms apart) in the base to take the two uprights. Drill a small hole (0.2 cms diameter) in the middle of each inset.

(2) Uprights



Set the uprights (each 12 x 2 x 1.0 cms) in the base insets with wood cement, insuring a firm joint by screwing very small screws through the base into the upright.

(3) Top Plate

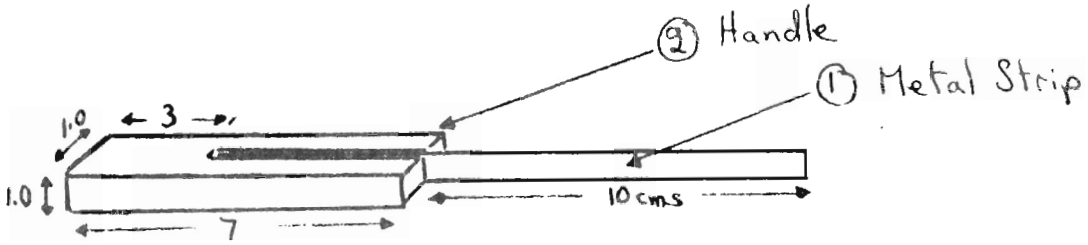


Cut the top plate (7 x 1.0 x 0.1 cms) out of aluminum or brass. Drill a small hole (0.2 cms diameter) at a distance of 1 cm from each end. Attach the top plate to the upright with very small screws.

Note:

A lens may be held in any position on the upright by means of rubber bands.

[illegible]/03 Interference Strips



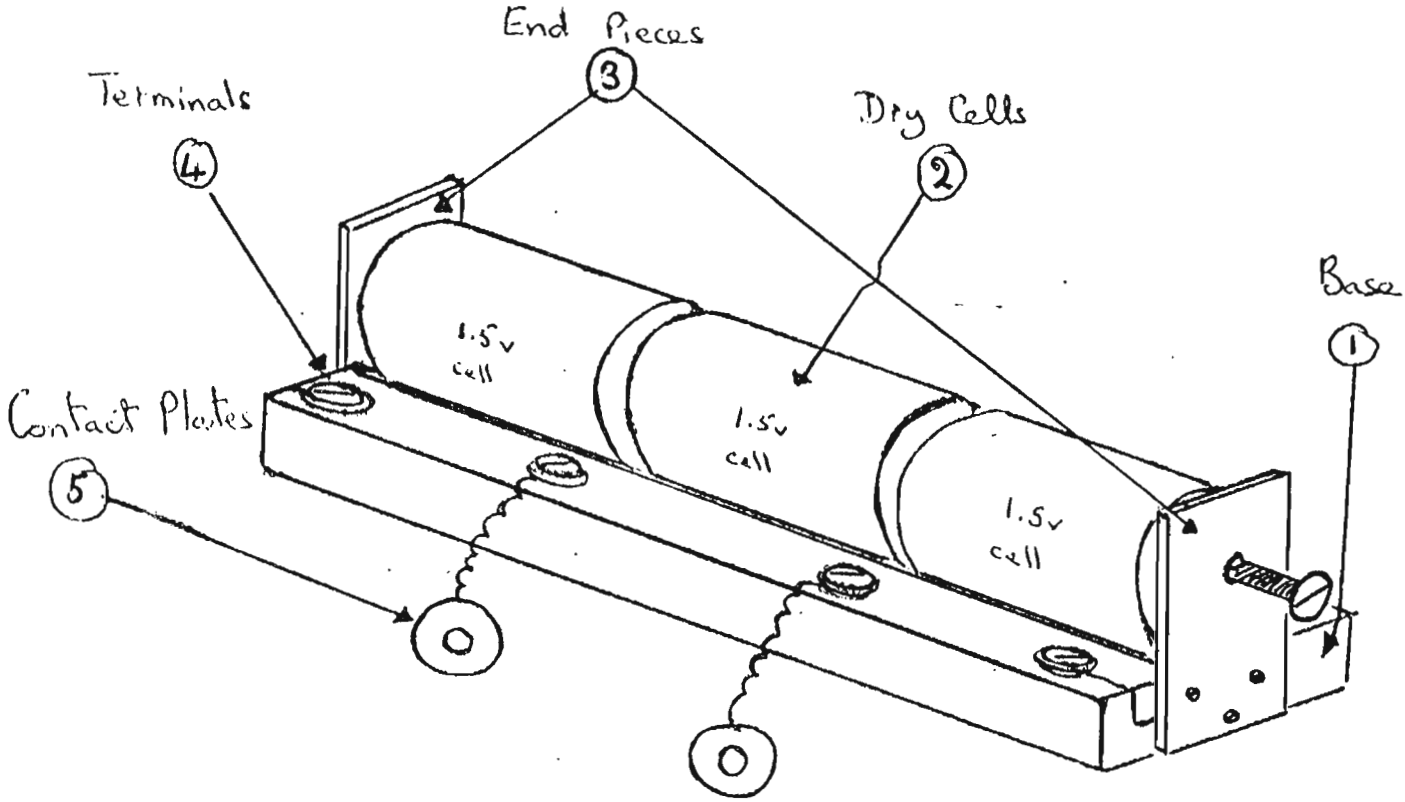
(1) Metal Strip

This may be of any desired metal. In this instance two are specifically recommended, namely copper and steel (packing case bands). Make the strip 14 cms long.

(2) Handle

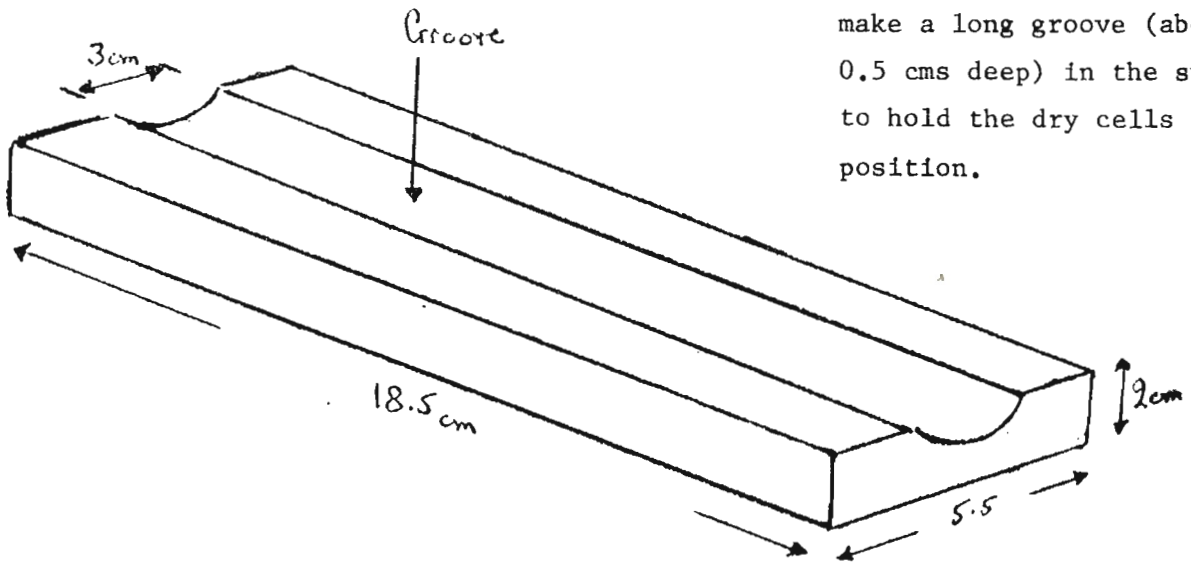
The handle is made from wood. Cut a slit (4 cms long) down the middle of the handle with a saw. Cement the metal strip into this inset with epoxy resin.

5.10/01 Dry Cell Holder with Cells



(1) Base

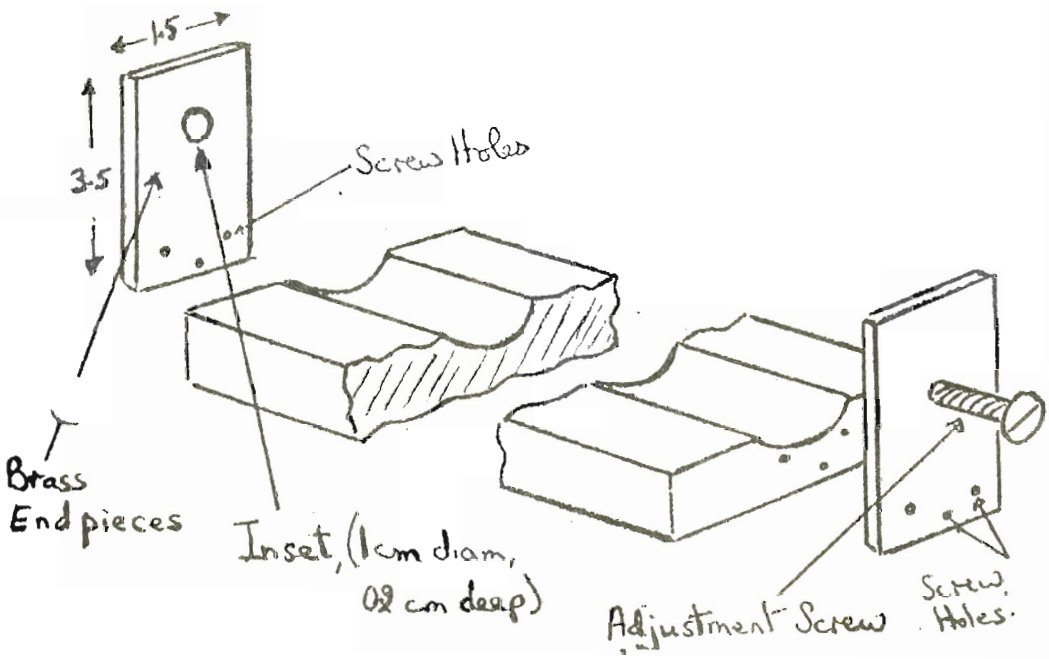
Cut the base out of soft wood, and use a curved chisel to make a long groove (about 0.5 cms deep) in the surface to hold the dry cells in position.



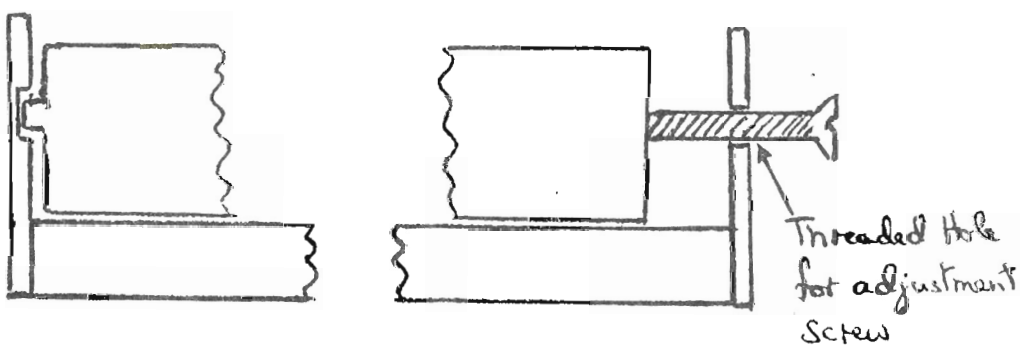
(2) Cells

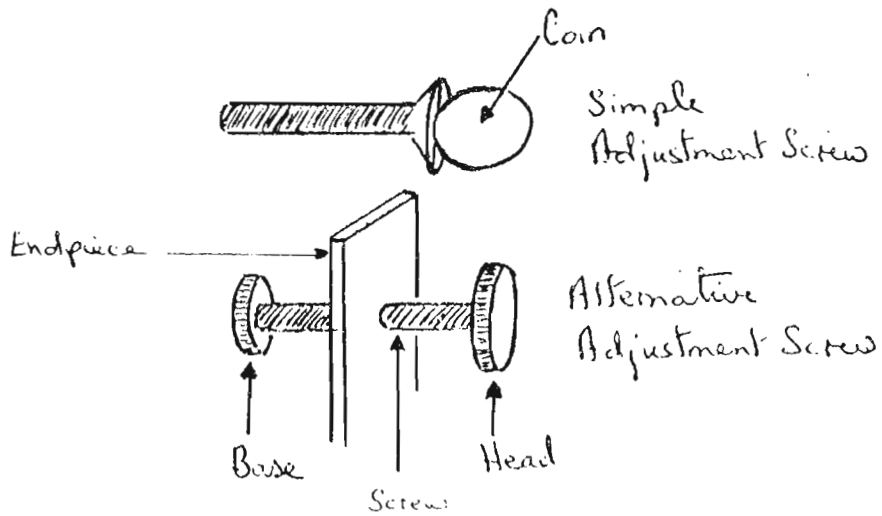
Place 3 dry cells in series
the groove of the base. The
groove should be from 1 to
1.5 cms longer than the 3
cells placed end to end, thu
allowing room for the placin
of contacts between the cell
and for adjustment of the
screw in one of the endpiece

(3) Endpieces



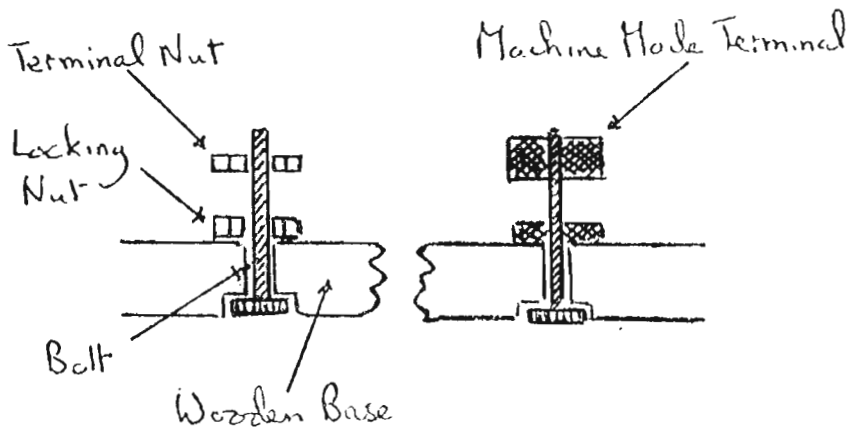
Cut the end pieces from a br
sheet (0.2 cms thick). Dril
3 small holes (0.2 cms diame
at the base of each endpiece
to facilitate attachment to
the base with small screws.
Place the dry cells on the
base to determine the height
of the mid point of the dry
cells, and then drill an
inset (0.9 cms diameter,
0.2 cms deep) at this height
in one endpiece, and a hole
(0.4 cms diameter) at the
same height through the othe
endpiece. Thread the newly
drilled hole to take the
adjustment screw (2 cms long





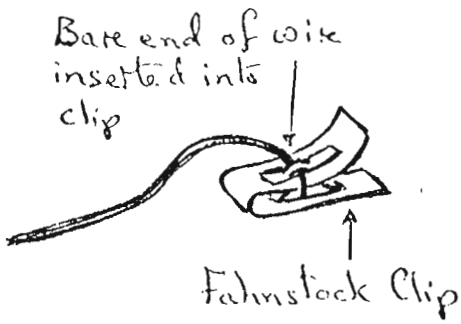
The adjustment screw described may have to be adjusted with the help of a coin, or some such device. A much more convenient adjustment screw could be made by a technician, or anyone familiar with a metal lathe, cutting the head and screw from a single piece of brass. The base would be made from a separate nut, firmly attached to the screw by damaging the threads at the end.

(4) Terminals



Make 4 terminals from brass bolts (approximately 2.5 cms long, 0.3 cms diameter). Two nuts are required, one to serve as a locking nut and one as a terminal nut.

Somewhat better nuts, which are more easily adjusted with the fingers, may be made by anyone familiar with a metal lathe. The terminal nut should be 0.5 cms thick, while the locking nut should be much thinner (0.2 cms). The diameter of both should be 1 cm.

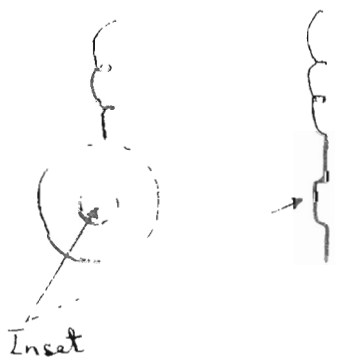


In some localities it is cheaper to purchase terminals on the local market. Check the availability of such items as Fahnstock Clips which can replace the above.

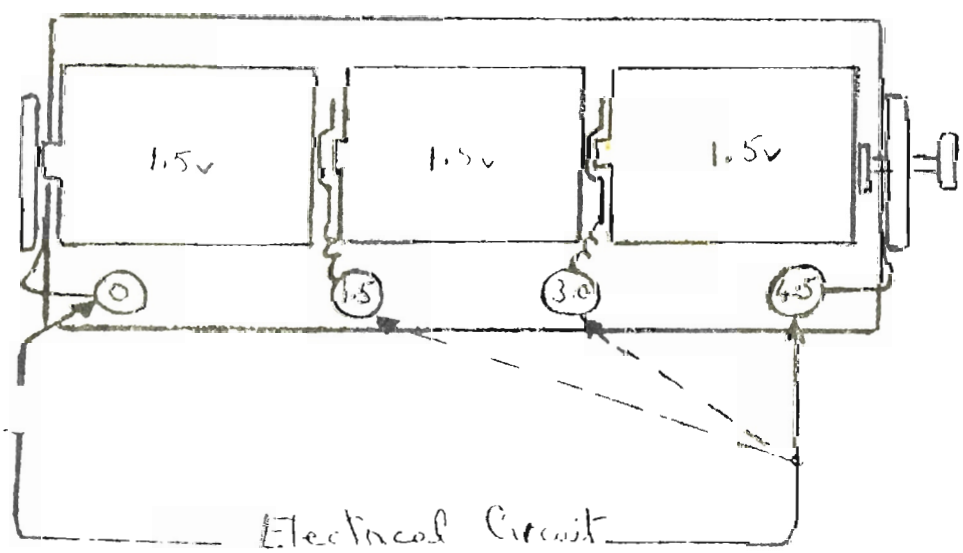
Make 4 insets (0.2 cms deep) at equal intervals underneath the front side of the base to take the bolt heads of the terminals. Insert the 4 bolts from below, and attach the locking nuts and terminal nuts.

Use copper wire to attach the end terminals to the endpieces, fastening the bare ends of the wire beneath the terminal locking nuts and brass endpieces. Similarly attach a length of copper wire (15 cms long) to each of the middle terminals.

(5) Contact Plates

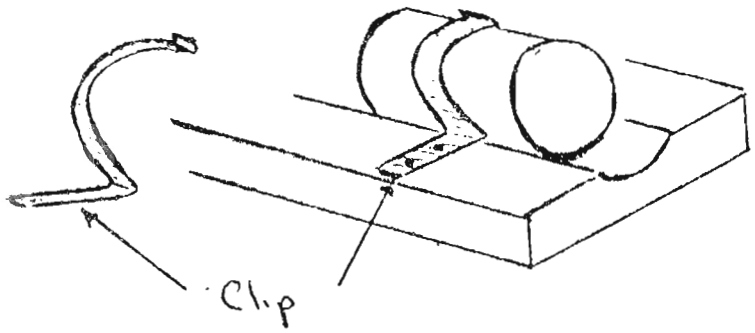


Cut two thin brass sheets into circular discs (1.5 cms diameter), and use a nail head or punch to make a central inset (1 cm diameter, 0.2 cms deep). Solder the two plates to the bare ends of the wire attached to the two middle terminals. The contact plates are placed between the first and second, and second and third cells, thus enabling the apparatus to provide an external circuit with 1.5, 3.0 or 4.5 volts according to the terminals connected to the circuit.

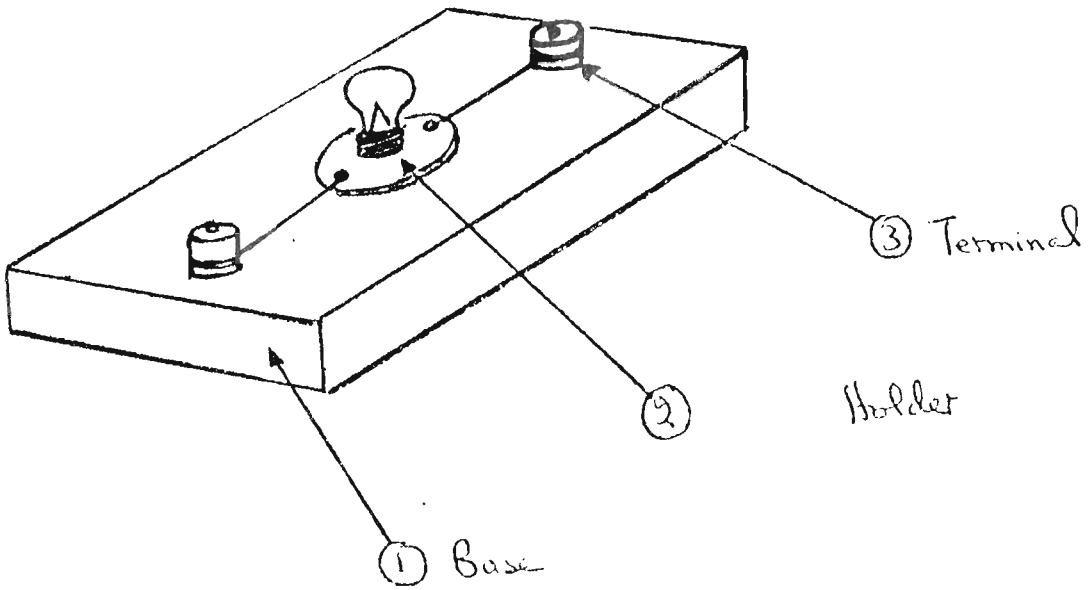


Notes:

(i) So long as the adjustment screw is not tightened too tightly the cells will remain firmly in the base groove. However, should any problem occur (e.g., due to bad alignment of the adjustment screw) the cells could be held more firmly in place by means of clips made from packing case bands.

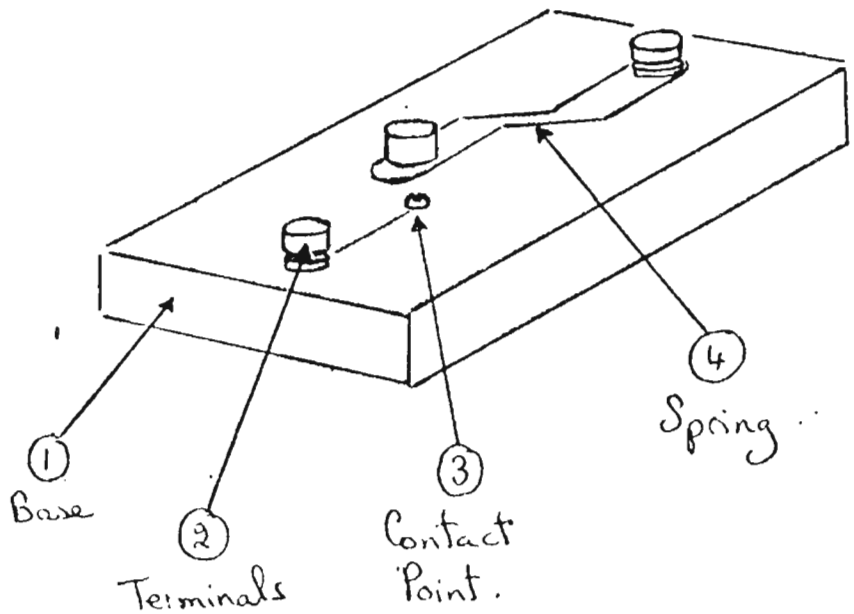


5.10/02 Bulb Holder with Bulb



(1) Base	Cut the base out of wood (7 x 3 x 1 cms approximately).
(2) Bulb Holder	Obtain a bulb holder (porcelain or metal) from the local market, and screw it onto the base. The holder should take a variety of local bulbs (e.g., 1.1 volts, 2.5 volts and 6.2 volts).
(3) Terminals	These are the same as the standard terminals described for the dry cell holder. Use magnet wire to connect the bulb and terminals, not forgetting to clean the ends of the wire.

5.10/03 Switch



(1) **Base**

Cut the base out of wood (7 x 3 x 1 cm).

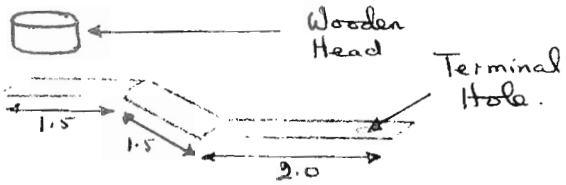
(2) Terminals

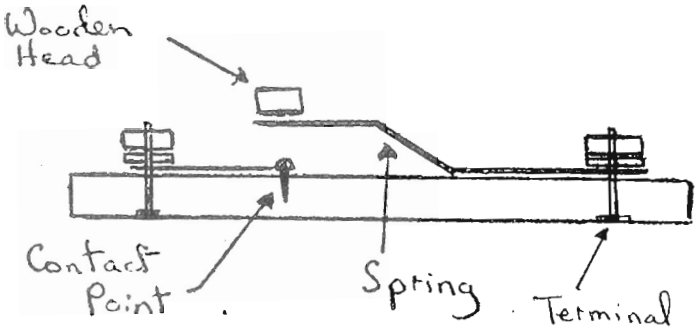
These are the same as the standard terminals described for the dry cell holder (5.10/01).

(3) Contact

Screw a brass screw into the wood (2 cms from one terminals) and connect it to the terminal **by means** of a short length of copper wire.

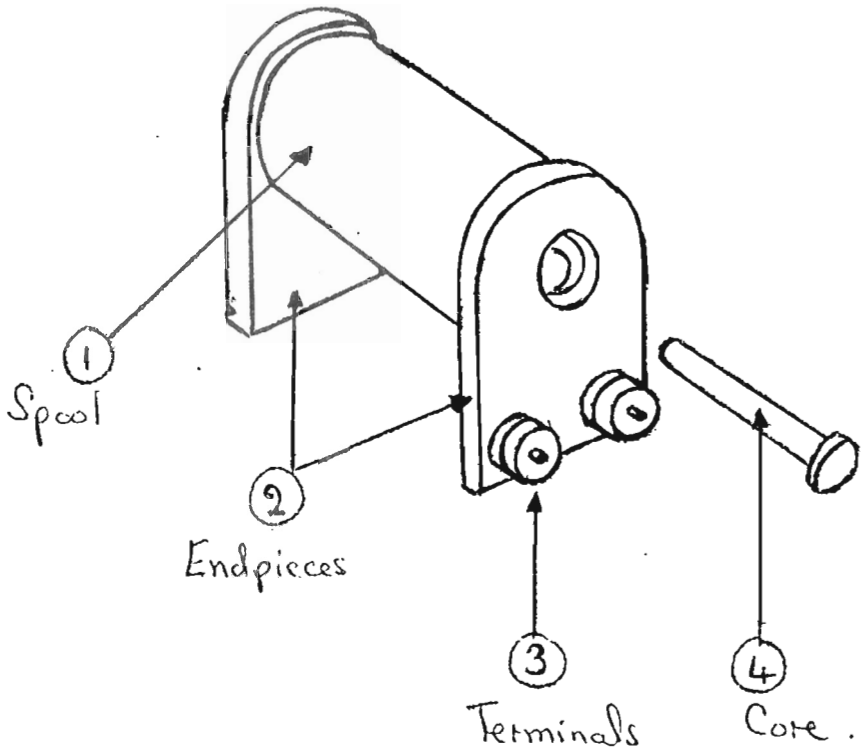
(4) Spring



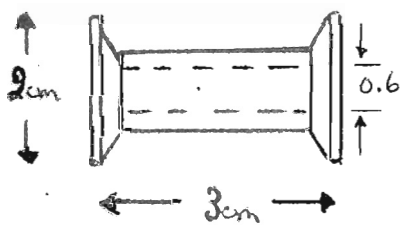


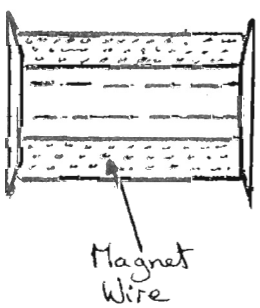
Make the spring out of a piece of brass sheeting (5 x 1 x 0.1 cms). Drill a small hole (0.3 cms diameter) in one end of the spring so that the terminal bolt will pass through it, and hold the spring in position by fastening the terminal locking nut. Cut a wooden head (1 cm diameter, 0.5 cms thick) and attach it to the free end of the spring with epoxy resin.

5.10/04 Multipurpose Coil with Cores



(1) Spool

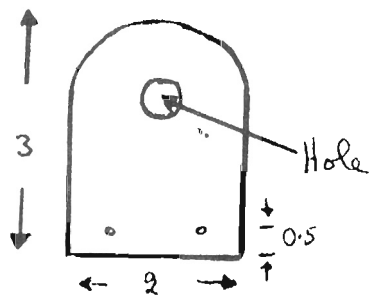




The size of the spool is not critical, but it does affect the spacing and size of multi-purpose coil holders used on the magnetic field apparatus and moving coil galvanometer described later in this section.

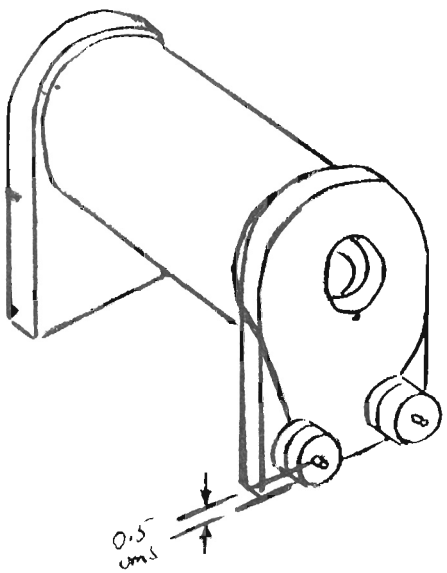
Wind 10 layers of magnet wire (#22) on to the spool, and then pass the loose ends of the wire through the last loops to prevent the coil unwinding. The winding of a coil by hand is a very tedious process, and it is well worth-while making a simple winding device to facilitate this (see notes below this item).

(3) Endpieces



Cut two endpieces from a piece of wood (0.4 cms thick), and cement them on to either end of the spool. Drill appropriate holes (0.6 cms diameter) in the endpieces so that the hole through the spool also extends through the endpieces.

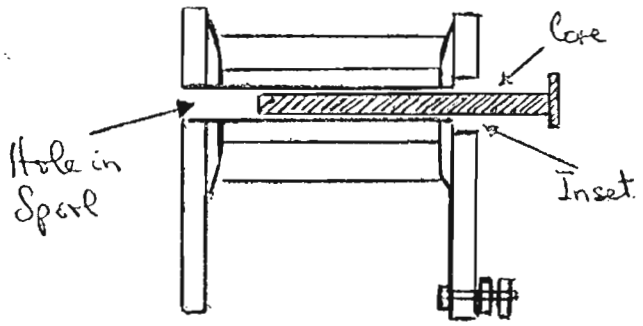
(3) Terminals



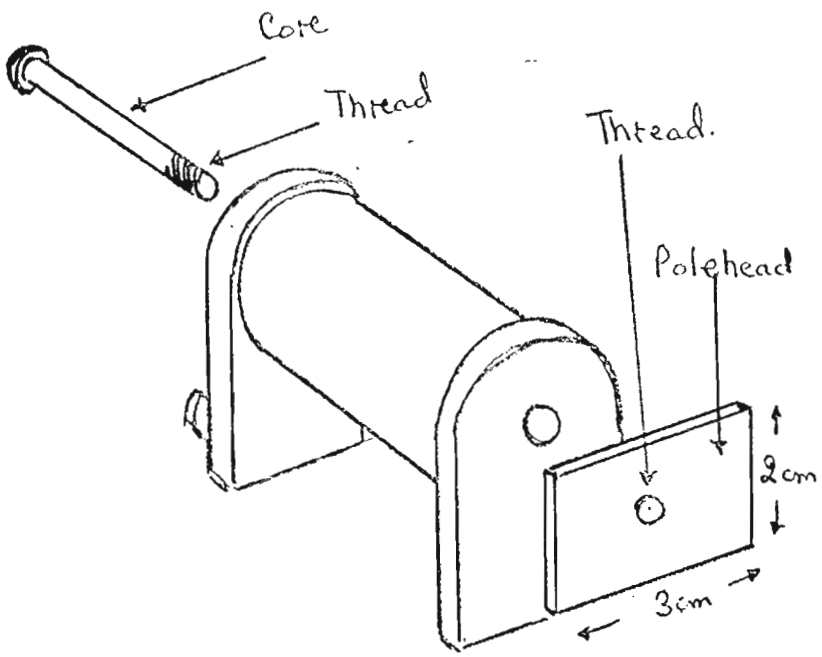
Make two terminals (see details under 5.10/01). Drill two small holes (diameter 0.3 cms) in the bottom of one endpiece and attach the terminals in the usual way. It will be found that the terminal bolt need only be 1.5 cms long in this case.

Clean the ends of the two wires from the spool coil, and fasten them under the locking nuts of the respective terminals. Make sure that it is possible to see the way in which the wire from each terminal begins to wind around the coil, for this makes it possible to determine the direction of the current around the coil, and hence the direction of the magnetic field produced.

(4) Core



Take a nail or bolt of diameter 0.5 cms, and cut off a length of 3.8 cms next to the head. Drill an inset (0.4 cms deep, 1.0 cms diameter) over the hole in the endpiece containing the terminals.

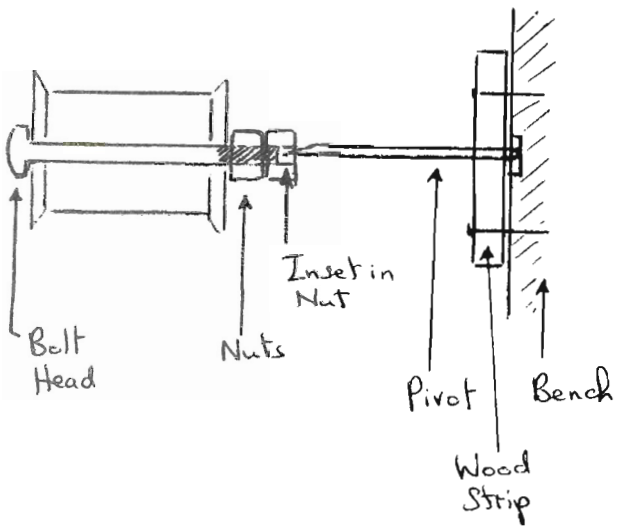


Cut an iron plate (2 x 3 x 0.3 cms), and drill a hole (diameter 0.4 cms) through its center. Thread the hole, and similarly put a thread (0.4 cms diameter) on the end of the core. Slide the core into the hole in the spool and attach the iron plate (polehead) to the end of the core.

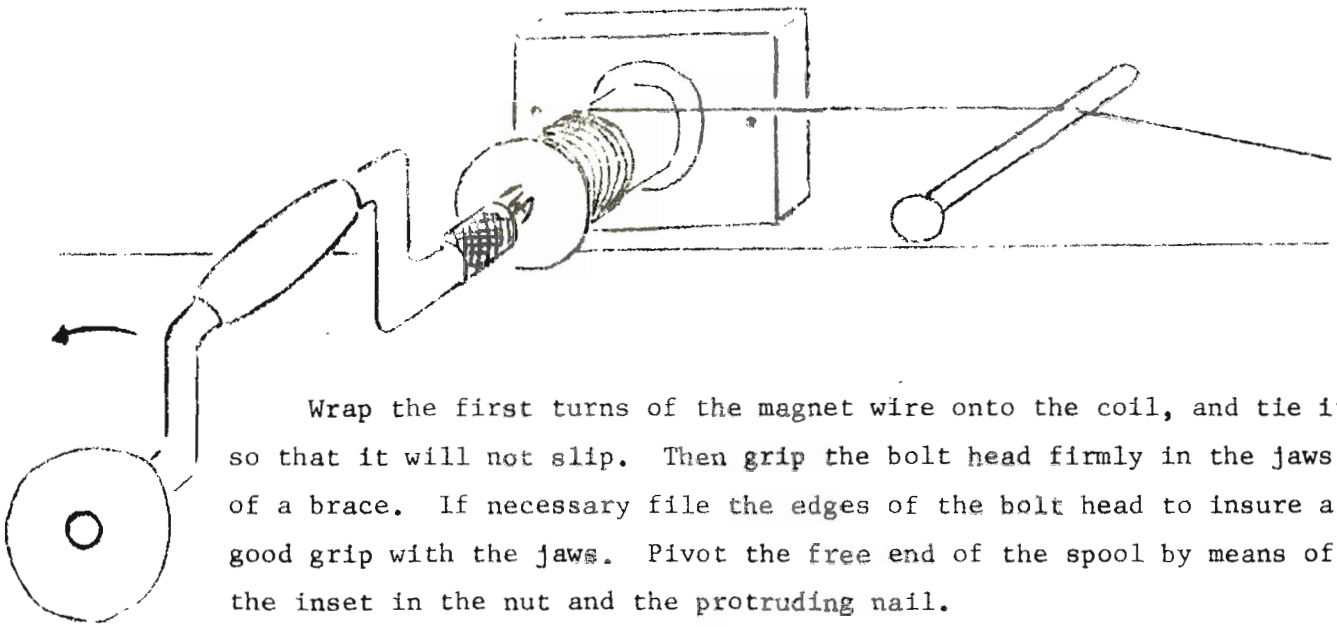
Note:

(i) The polehead is added to the core when uniform magnetic fields are to be produced (e.g., in the magnetic field apparatus and in the moving coil galvanometer).

(ii) The following is one of many possible methods of winding the multipurpose coil with magnet wire. Pass a bolt (4 cms long) through the hole in the spool and hold it in position with two nuts at the other end. The length of the bolt should be such that the second nut only just bites onto the thread of the bolt, thus leaving an inset which may be used as a pivot point. It may be necessary to adjust the length of bolt thread available to the nuts by inserting washers between the nuts and the spool (or between the bolt head and spool).



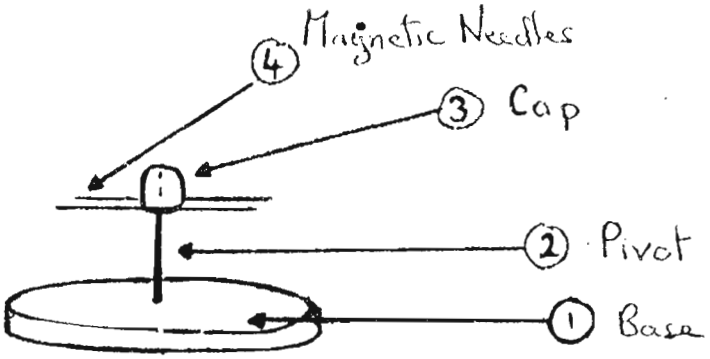
Hammer a nail (3 cms long, 0.3 cms diameter) through a strip of wood (10 x 5 x 1 cm approximately), and nail the strip to the side of a bench so that the nail protrudes as a pivot. Hammer a second nail (10 cms long, 0.5 cms diameter) into the bench at the same height as the pivot nail, but about 50 cms from it.



Wrap the first turns of the magnet wire onto the coil, and tie it so that it will not slip. Then grip the bolt head firmly in the jaws of a brace. If necessary file the edges of the bolt head to insure a good grip with the jaws. Pivot the free end of the spool by means of the inset in the nut and the protruding nail.

Get your partner to hold the loose end of the magnet wire over the second tape in such a way that the wire is kept taut during winding. Now with the wire under tension wind the wire onto the spool by turning the brace.

5.10/05 Compass



(1) Base

Cut the base from a thin strip of wood (0.3 cms thick) so as to form a disc (2.5 cms diameter). Although less durable, a cork disc would produce a reasonable base.

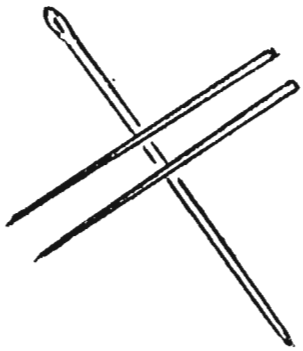
(2) Pivot

Cut a 1 cm length off the pointed end of a needle (0.1 cm diameter). Drill a small hole (0.1 cm diameter) in the middle of the base and set the needle in the hole with epoxy resin so that it stands vertically, pointed end uppermost.

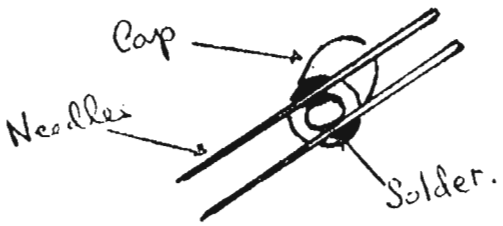
(3) Cap

Take a brass rod (0.5 cms long) and cut off a length of 0.5 cms. Holding the rod firmly in a clamp drill a hole (0.3 cms diameter, 0.3 cms deep) along the axis of the rod.

(4) Magnetic Needles



Take two needles and cut each to about 2 cms long. If the needles are tapered determine the center of gravity of each by balancing the needles over another needle, which serves as a pivot. Mark in the positions of the centers of gravity of the needles.

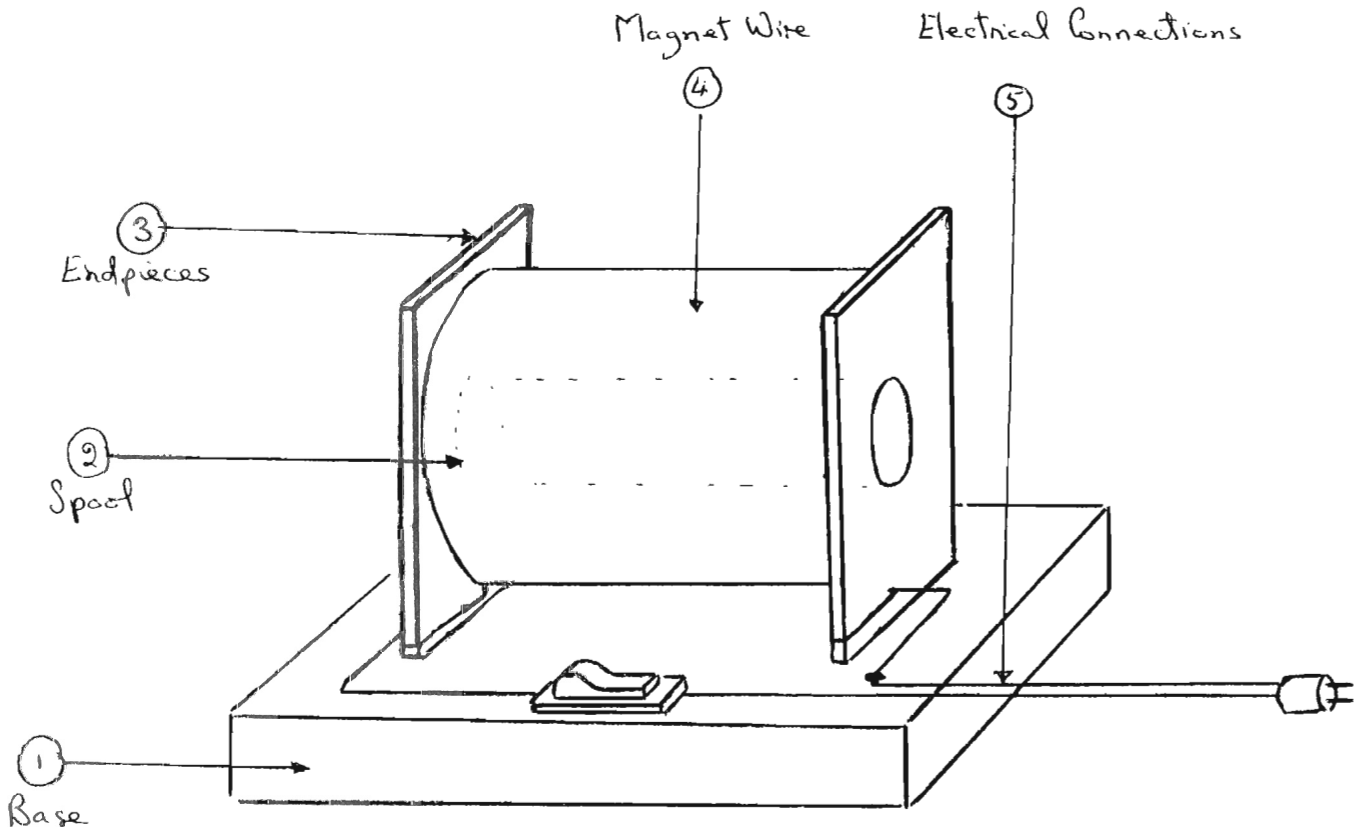


Hold the needles parallel to one another and drop some solder on the base of the cap. Attach the needles to the cap at their centers of gravity by placing them in the still molten solder.

Finally, place the cap and needles inside a magnetizing coil (see 5.10/06) to magnetize them, and then place the cap on top of the pivot.

Note the ends of the needles which point to the North, and mark these (e.g., with paint).

5.10/06 Magnetizing Coil and Magnets

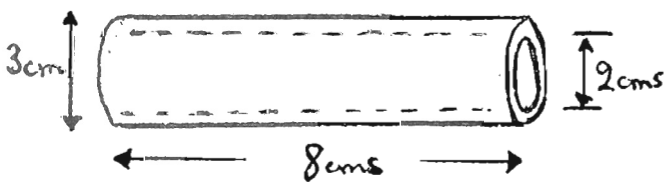


(1) Base

Cut the base out of wood (15 x 15 x 2 cms).

(2) Spool

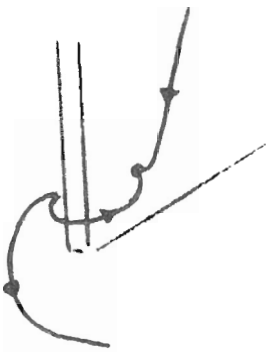
Take a wooden dowel (a broomstick of diameter 3 cms) and cut off a length of 8 cms. Drill a hole (diameter 2 cms) along its axis.



(3) Endpieces

Cut the endpieces (8 x 8 x 0.5 cms) out of wood. Drill a hole (2 cms diameter) in the middle of each endpiece. Use wood cement to attach the endpieces to either end of the spool.

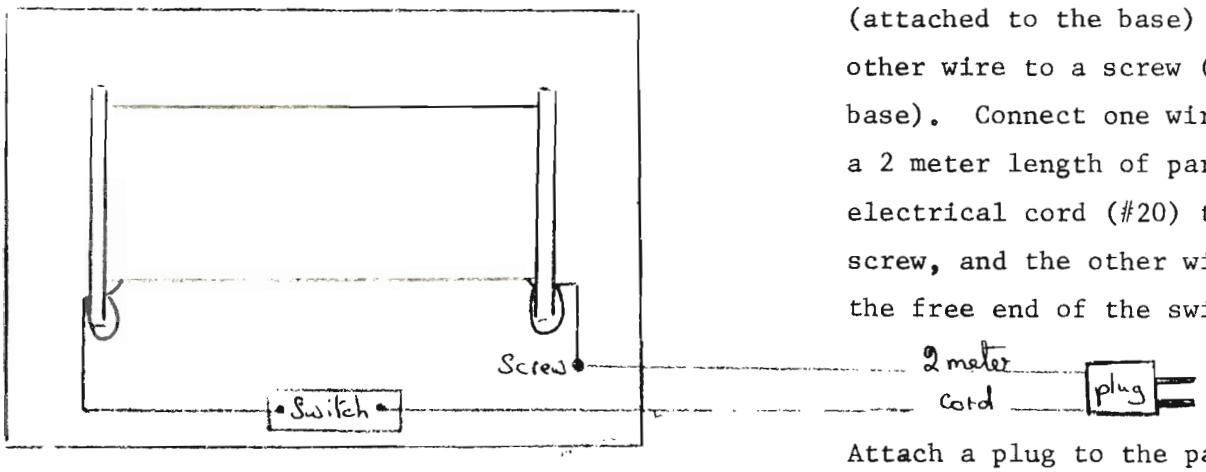
(4) Magnet Wire



Obtain 1 kilo of magnet wire (#22) and wind it all onto the spool (see notes) taking care to leave about 25 cms of both ends of the wire free to make appropriate connections. Drill a small hole in each endpiece and loop the wire ends through these holes to prevent unwinding of the coil.

Make two insets (8 cms long, 0.5 cms wide, 0.2 cms deep) in appropriate positions of the base to hold the endpieces. Use wood cement to fix the endpieces firmly in the insets.

(5) Electrical Connections



Connect one of the loose wires from the coil to a switch (attached to the base) and the other wire to a screw (in the base). Connect one wire from a 2 meter length of parallel electrical cord (#20) to the screw, and the other wire to the free end of the switch.

Attach a plug to the parallel cord.

Cover all the magnet wire (the whole coil and the screw) with insulating tape to act as a safety measure. (It does in fact make good sense to pass the wire from the coil to the underside of the base to make the connections below, rather than above, the base).

Notes:

(i) To magnetize an item, Place a suitable steel specimen in the center of the coil. Switch the current quickly on and off. The specimen will be magnetized on removal from the coil.

Ticonal is an ideal alloy for making magnets, but is rarely available on local markets. High quality tool steel is a good second best, and is generally found in good quality tools (chisels, screwdrivers, drill bits, etc.), as well as domestic items such as razor blades and sewing needles.

Unfortunately, the "high grade steel" sold on many local markets tends to be of poor quality, and does not retain magnetism well. However, if the steel is heated to red heat in an oxy-actylene flame, and then quenched in cold water,

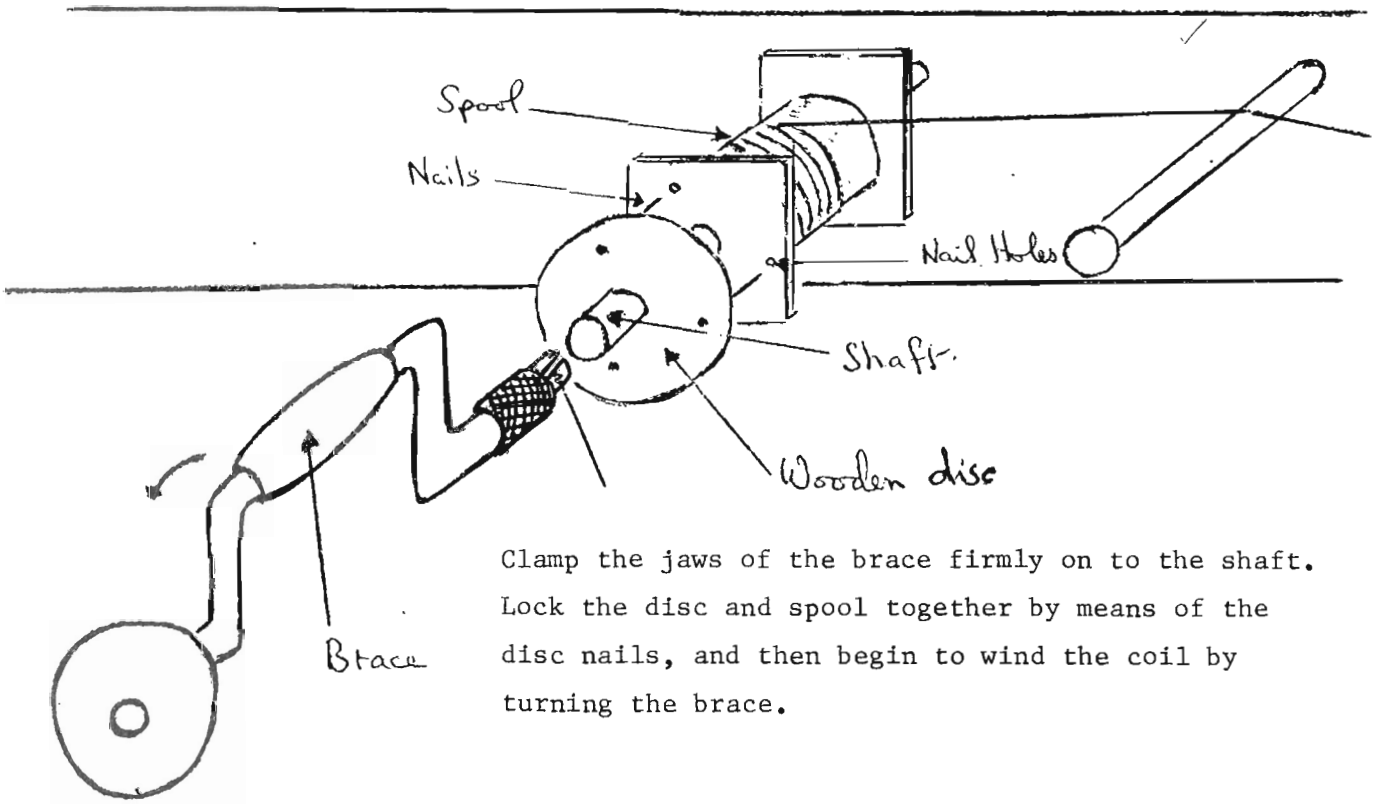
it tends to be hardened, and hold magnetism somewhat better. (It should be noted that "steel rods" used in construction work for reinforcing concrete is a very soft iron, and cannot be permanently magnetized.

This magnetizing coil is designed for use with 220 volt mains supply, and is capable of producing extremely strong magnets. It would also work with a 110 volt supply, but the magnetism induced in a given specimen would be weaker than with a 220 volt supply. The magnetizing coil should never be switched on and left on, as it would overheat and burn out. It is designed for usage over very short periods of time (2 or 3 seconds only).

To demagnetize a specimen, place the magnet inside the coil and hold its end very firmly. Switch on the current, and remove the specimen from the coil maintaining a firm grip on it. The current is not switched off until the specimen is completely out of the coil.

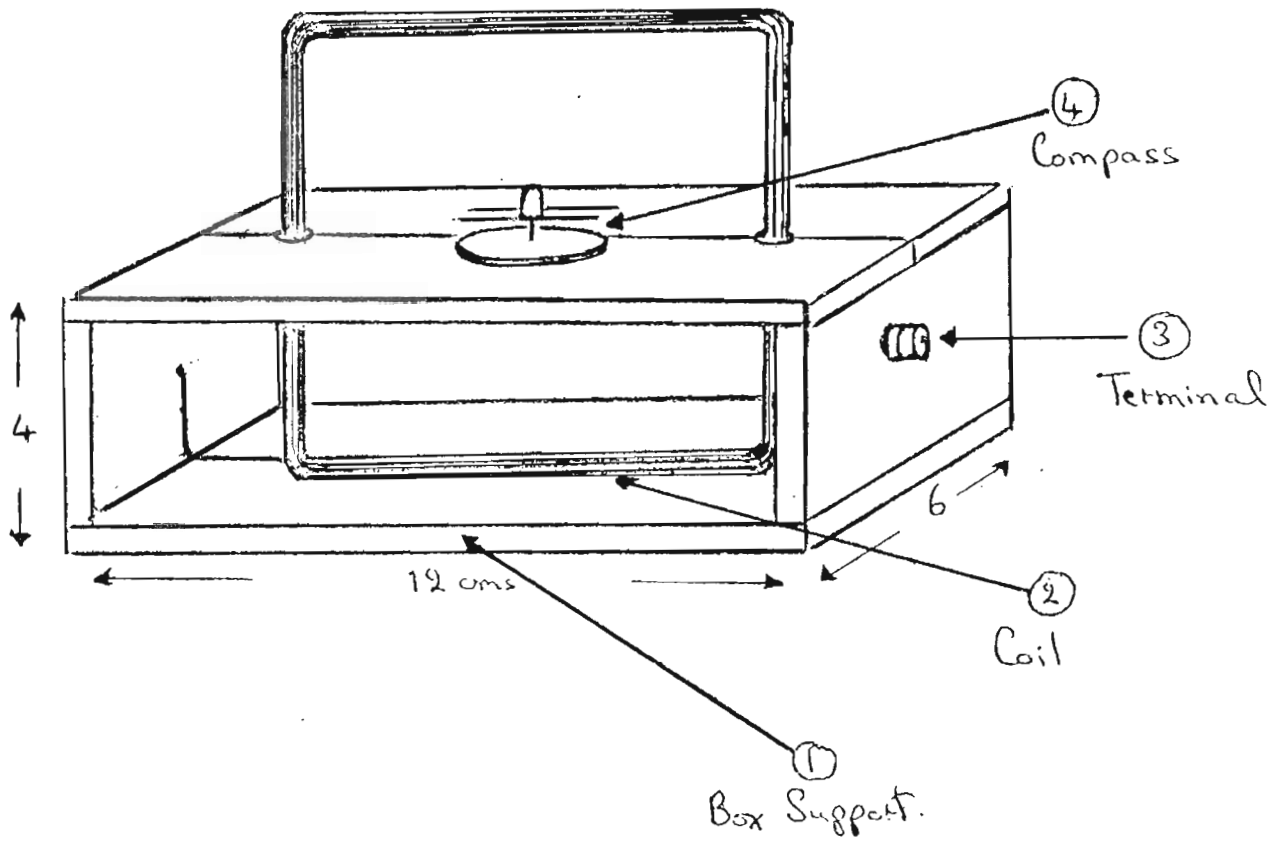
(ii) The winding of the spool may be facilitated by the use of a brace. Hammer two large nails (15 cms long, 0.7 cms diameter) into the side of a bench so that they protrude horizontally some 50 cms apart. Place the spool to be wound on one of the nails. Fasten the first turn of magnet wire around the spool in such a way that it will not slip on turning the spool. Then get your partner to hold the wire taut over the second nail so that it may be wound under tension.

Attach a short shaft (15 cms long, 1 cm diameter) to the center of a circular disc (7 cms diameter, 0.5 cms thick) by means of a central screw and wood cement. Hammer 3 nails through the perimeter of the disc and drill 3 corresponding holes in the endpiece of the spool to take the protruding nails.



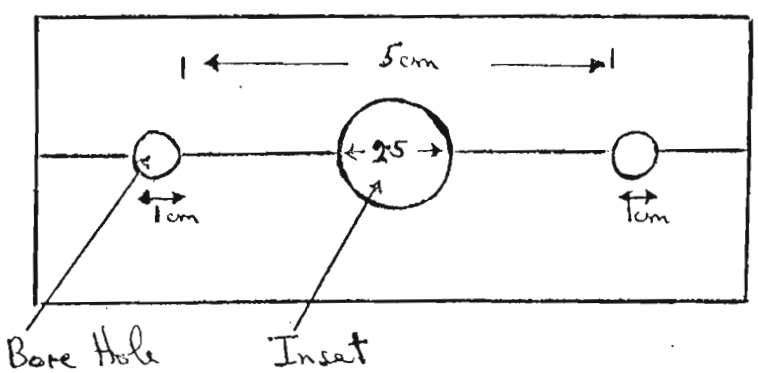
Clamp the jaws of the brace firmly on to the shaft. Lock the disc and spool together by means of the disc nails, and then begin to wind the coil by turning the brace.

5.10/07 Tangent Galvanometer

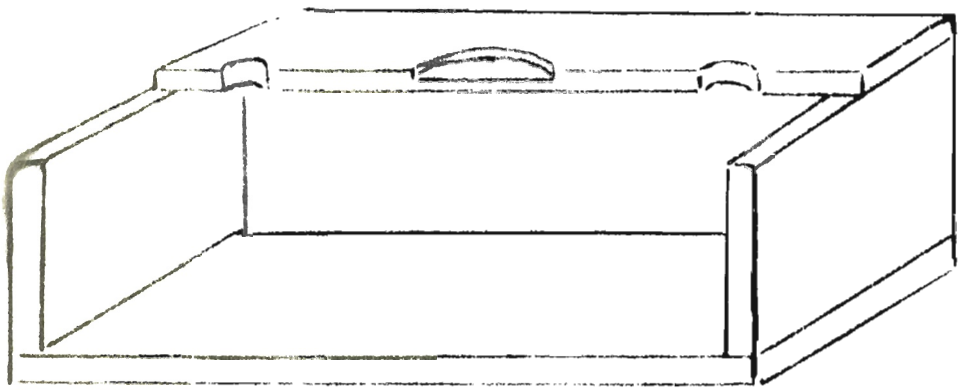


(1) Box Support

Make a 4 sided wooden support from a base (12 x 6 x 1 cm), 2 sides (each 6 x 2 x 1 cm) and a top platform (12 x 6 x 1 cm). Fasten the base and sides together with small screws and wood cement, but do not put the platform in position yet.

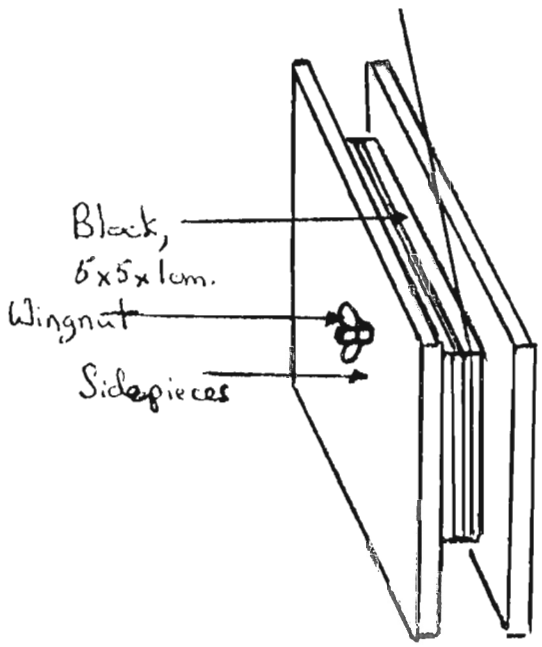


Drill an inset (0.2 cms deep) into the middle of the platform, and two holes right through the platform to take the coil. Cut the platform into two equal



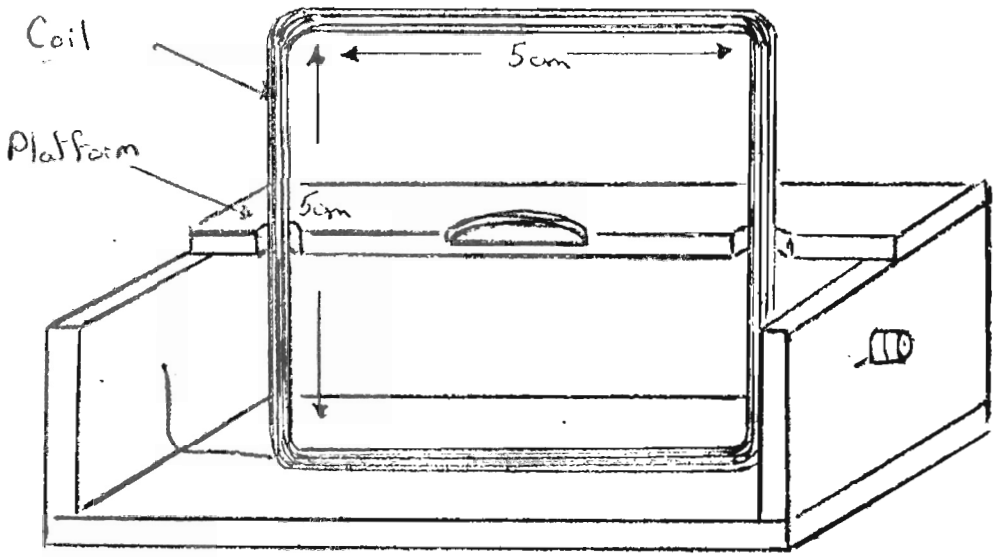
halves fastening one half only in position with small screws and wood cement.

(2) Coil



To make the coil (100 turns, #24 magnet wire) a simple winding device is desirable. This may be made from a block of wood (5 x 5 x 1 cm) and two hardboard sides (8 x 8 x 0.5 cms). Drill a hole through the middle of the block and sides and hold the parts together with a bolt and wingnut.

Wind the magnet wire on to the block layer by layer, adding a coat of varnish to each layer to hold the turns together. Wind 100 turns on the block, and make sure that about 20 cms of both ends of the wire are left free to make the appropriate connections.



When the varnish is dry remove the coil from the block (simply by releasing the sides) and sit the coil vertically on the base.

Attach the second half of the platform with small woodscrews and wood cement.

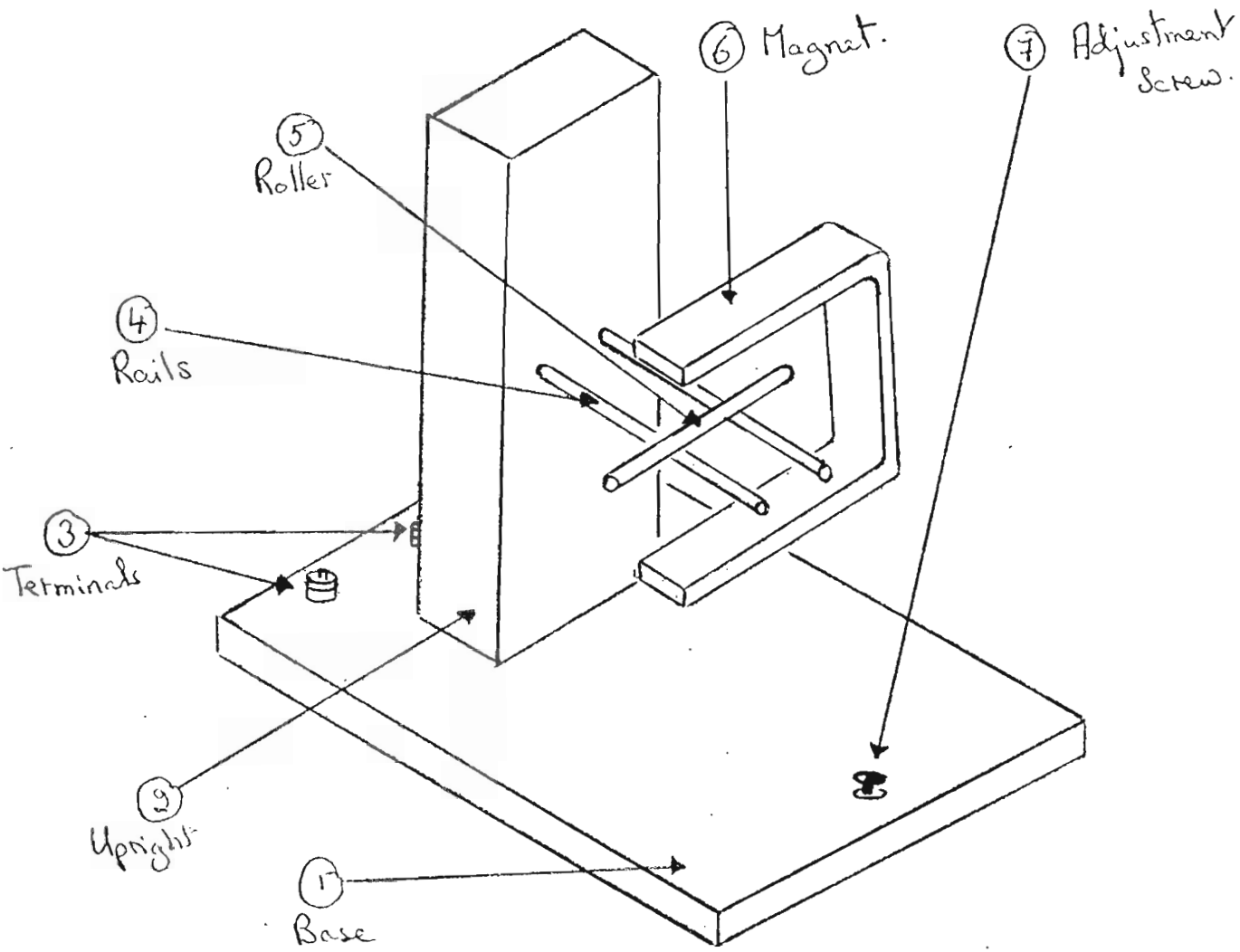
(3) Terminals

Two terminals (described under 5.10/01) are required. Fix one on either side of the box support, and attach the two wires from the coil to the terminals. Don't forget to clean the ends of the wire with sandpaper.

(4) Compass

Place the compass (described under 5.10/05) in the inset on the platform.

5.10/08 Magnetic Field Apparatus



(1) Base

Make the base out of wood (10 x 7 x 1 cms).

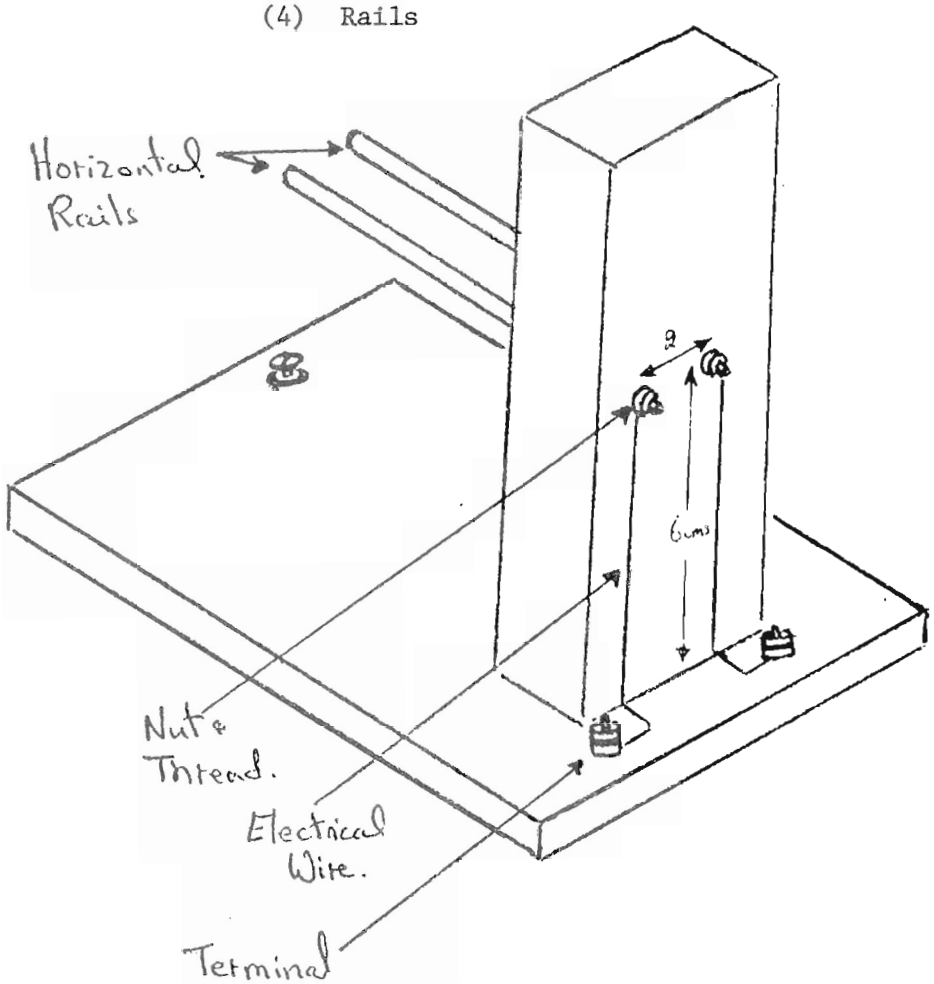
(2) Upright

Attach the wooden upright (11 x 4 x 2 cms) vertically to the base with two wooden screws passed through the base (4 cms from one end). Use wood cement to insure a firm joint between the upright and base.

(3) Terminals

Two terminals (described under 5.10/01) are required. Screw these into the base behind the vertical support.

(4) Rails



Cut two rails (each 5 cms long) from a brass rod (0.3 cms diameter). Cut a thread on the end of each rod and find a nut to fit each.

Drill two horizontal holes (0.3 cms diameter, 2.0 cms apart) through the support to take the rods. It is important that these two holes should be exactly at the same height (6 cms) above the base, and exactly horizontal. Pass the rails through the support. A little epoxy resin will hold the rails firmly in position, but avoid getting the resin (an insulator) on the protruding rails or threads. Attach the nuts to the protruding threads of the rails.

Connect the terminals to the above nuts with magnet wire (#24).

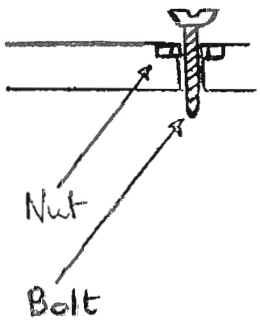
(5) Roller

The roller must be very light. Cut an aluminum rod (4 cms long, 0.3 cms diameter) for this purpose.

(6) Magnet

A strong horseshoe magnet may be handheld in the position illustrated to create a vertical magnetic field at right angles to the horizontal rails.

(7) Adjustment Screw



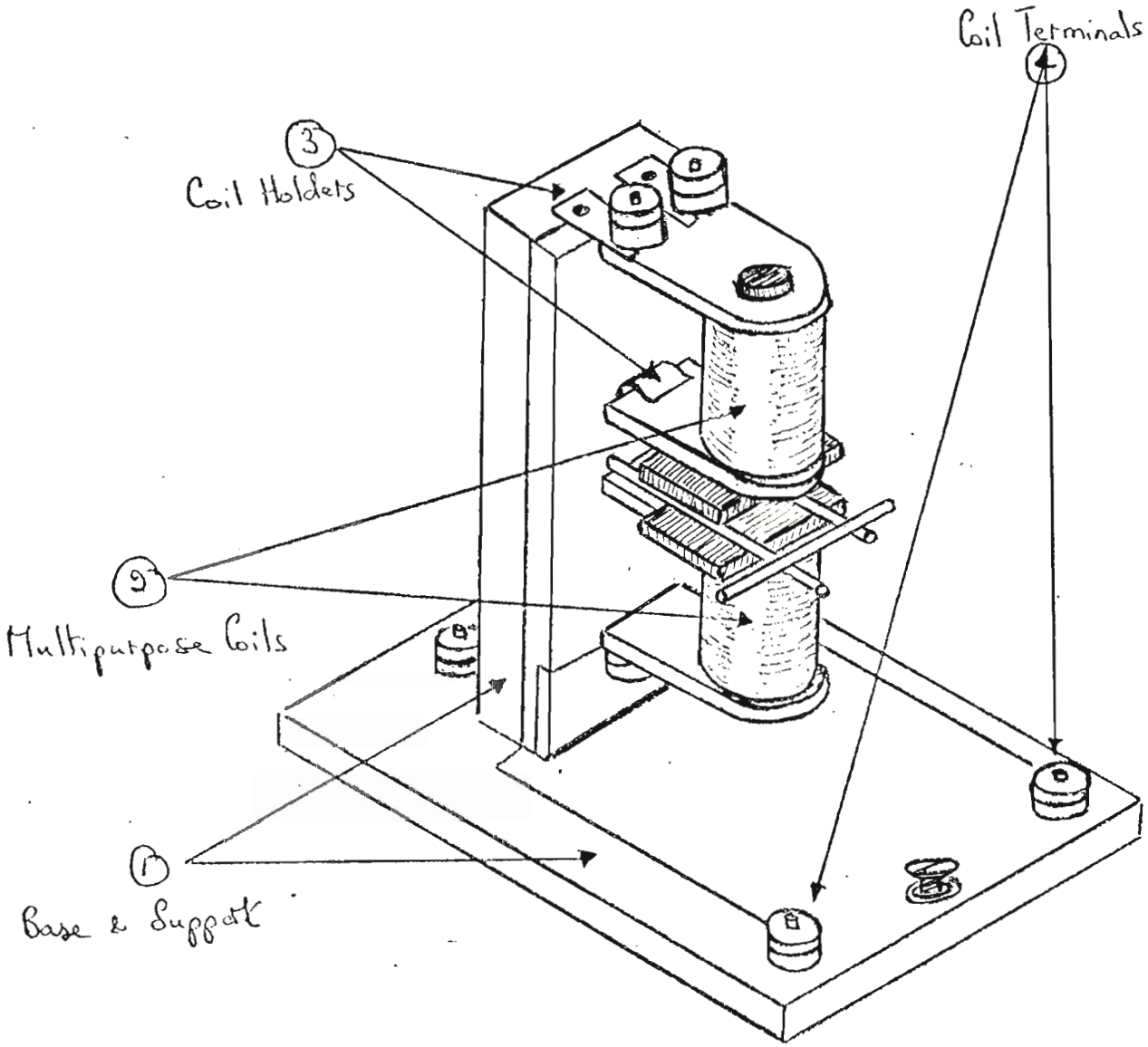
Drill a hole (diameter 0.3 cms) through the base to take a bolt (2.0 cms long, 0.2 cms diameter). Inset a corresponding nut over the hole by striking it into position with a hammer. Thread the bolt through the nut.

Two similar adjustment screws at the opposite corners of the base would make the levelling of the apparatus simpler.

Notes:

(1) Should there be any difficulty in obtaining a good strong horseshoe magnet then multipurpose coils may be used instead, as described in the next item.

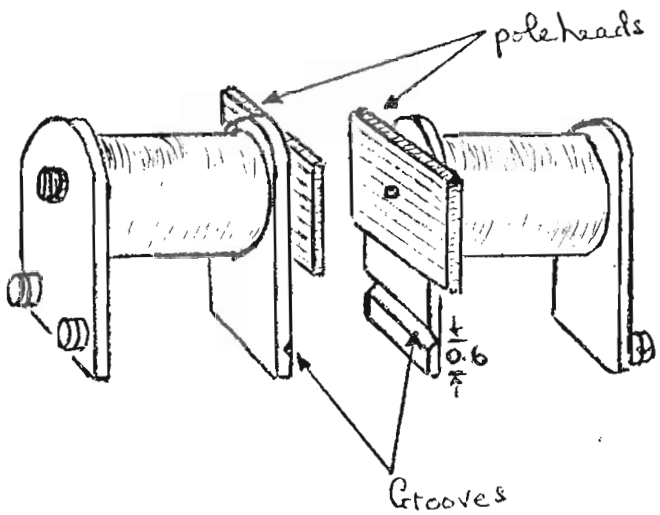
5.10/09 Magnetic Field Apparatus with Multipurpose Coils



(1) Base and Support

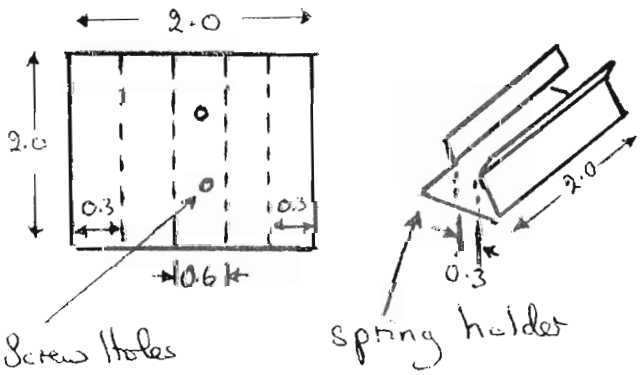
This is the foregoing magnetic field apparatus (5.10/08) with the magnet removed. The components mentioned below enable the setting up of an electromagnetic field to replace that created by the horseshoe magnet.

(2) Multipurpose Coils

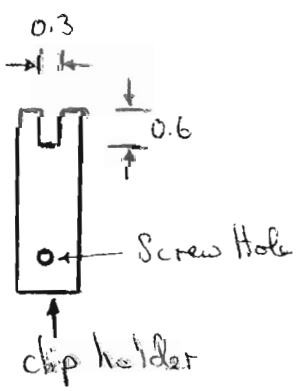


Two multipurpose coils complete with poleheads (see 5.10/04) are required. Cut a horizontal groove in the front endpiece of each, just beneath the poleheads, to insure a good grip for the coil holders.

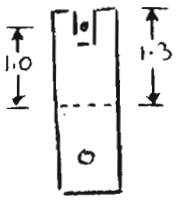
(3) Coil Holders

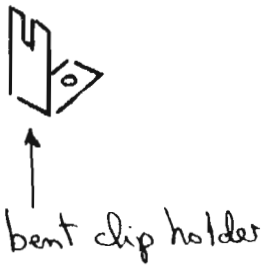


Cut a sheet of brass (2 x 2 x 0.2 cms), and make two spring holders. Attach these horizontally to the vertical support 1 cm above, and 1 cm below, the horizontal rails. Clip the multipurpose coils temporarily in the spring holders, and mark out the positions for the clip holders at the opposite end of each coil.

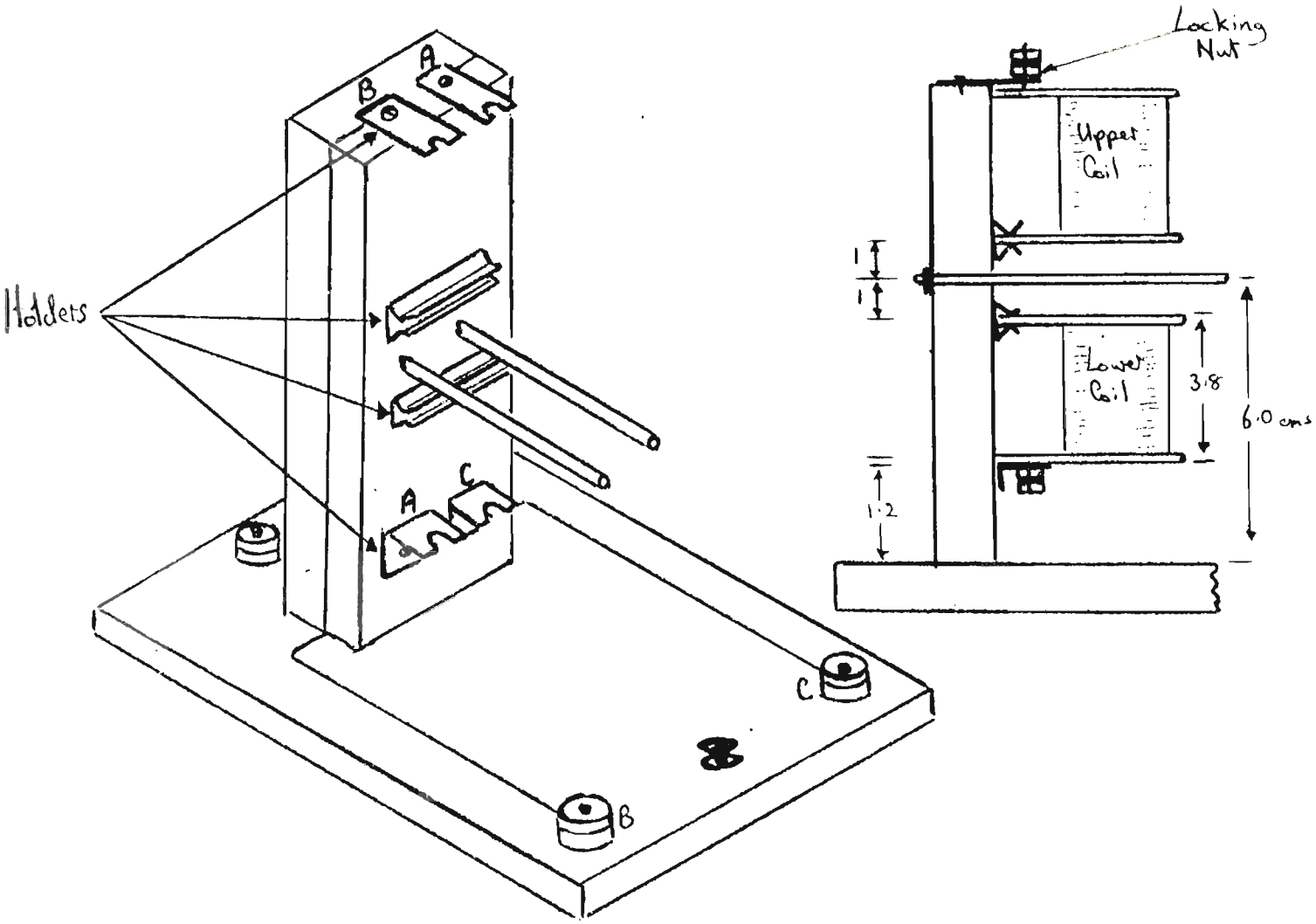


Cut 4 clip holders (3.0 x 0.8 x 0.05 cms) from a thin brass sheet. Cut the top off the vertical support so that this is level with the top of the upper coil. Take two clips, and fasten the slotted end of each under the locking nut of a terminal on the top end of the coil. Then holding the coil close to the support, attach the clips to the support with small screws.





The two remaining clips must be bent to hold the bottom end of the lower coil. Measure the distance from the center of the terminal to the support. Let's say this is 1 cm, then the clips must be bent at right angles at 1.3 cms from the slotted end. Fit the slotted end of each clip under the locking nut of a terminal on the lower coil, and then screw the clips to the vertical support.

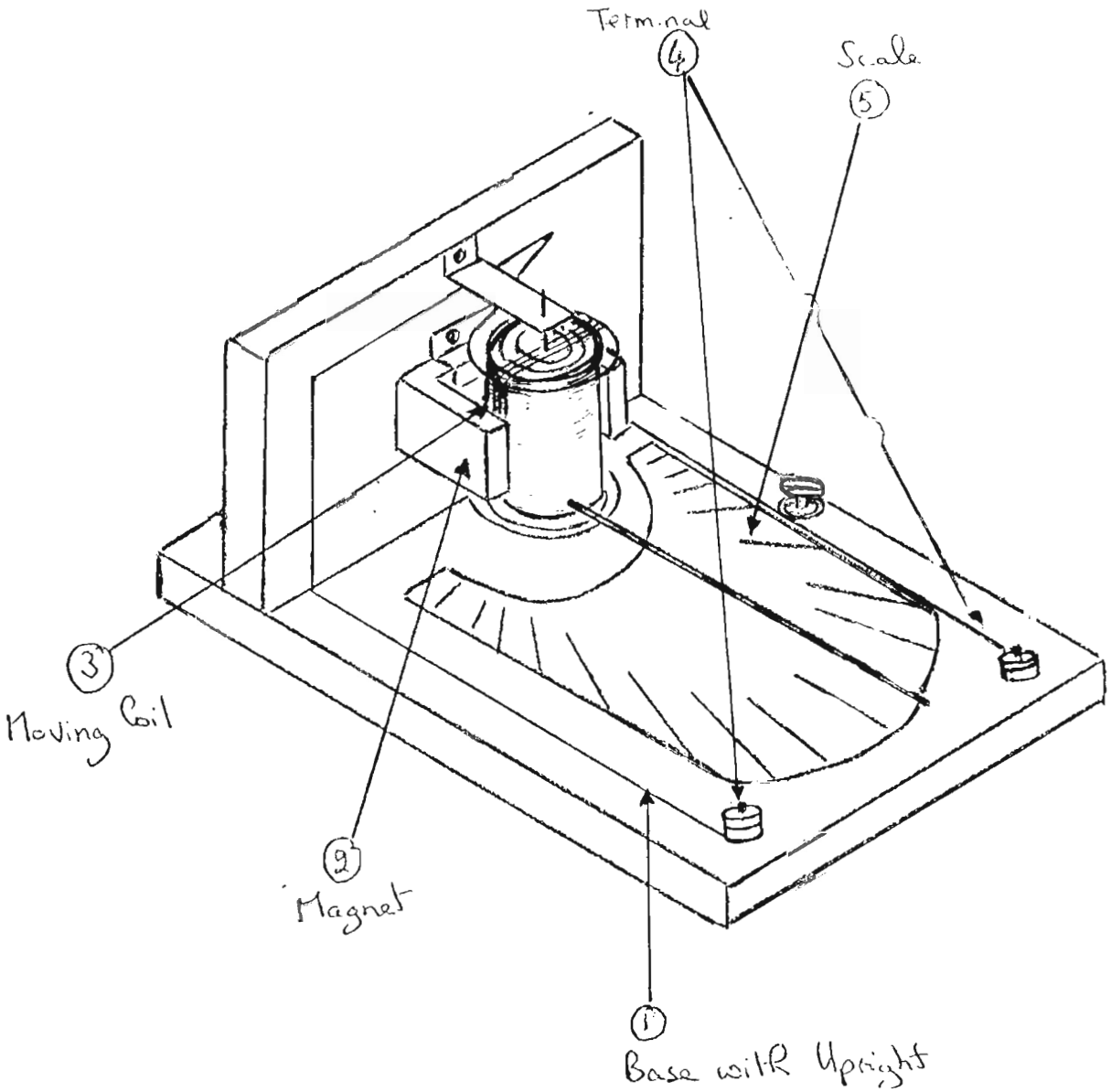


(4) Terminals

Two terminals (described under 5.10/01) should be attached to the front of the base.

Finally connect the terminals and coil holders by magnet wire (#24) so that electrical connections exist between points A to A, B to B and C to C (see above diagram), thus insuring that current will flow through the multipurpose coils in the same direction once the terminals at the front of the base are connected to a circuit.

5.10/10 Moving Coil Galvanometer

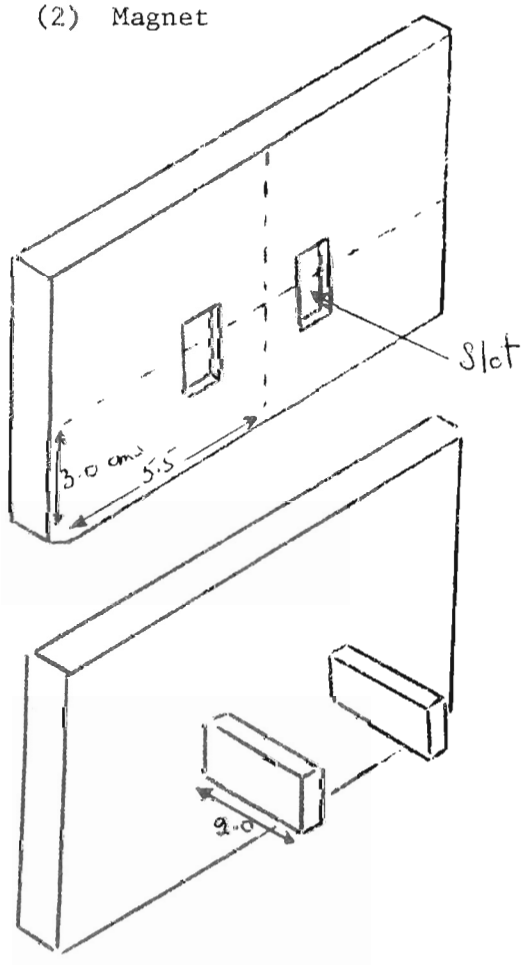


(1) Base with Upright

Cut the base out of wood (14 x 11 x 1 cm). Attach the wooden upright (6 x 11 x 1 cm) to the base with two screws from beneath the base and with wood cement to make a firm joint. Leave enough room (2 cms) behind the upright to permit space for two terminals to be fitted.

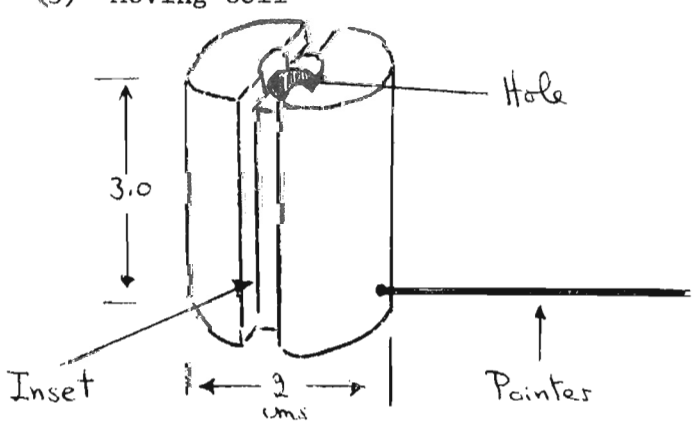
Make an adjustment screw (as described under 5.10/08) to fit in one side of the base. Similar screws could well be placed at the two opposite corners of the base for more accurate levelling of the apparatus.

(2) Magnet

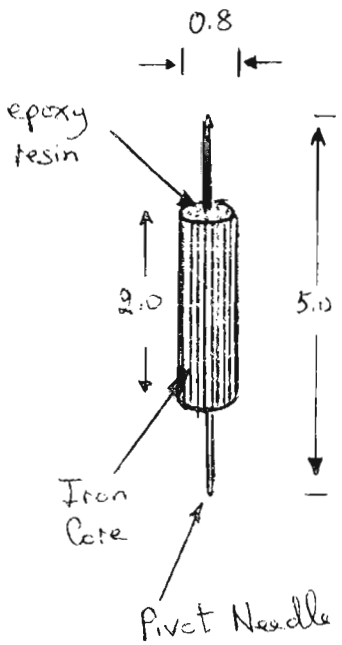


Obtain a strong horseshoe magnet in which the separation of the two sides of the horseshoe is approximately 3 cms (or a little more). Make slots in the upright as illustrated to allow the magnet to be pushed through the upright so as to protrude a distance of 2 cms. Once the moving coil (below) has been fixed finally in position fix the magnet firmly in the upright with epoxy resin.

(3) Moving Coil



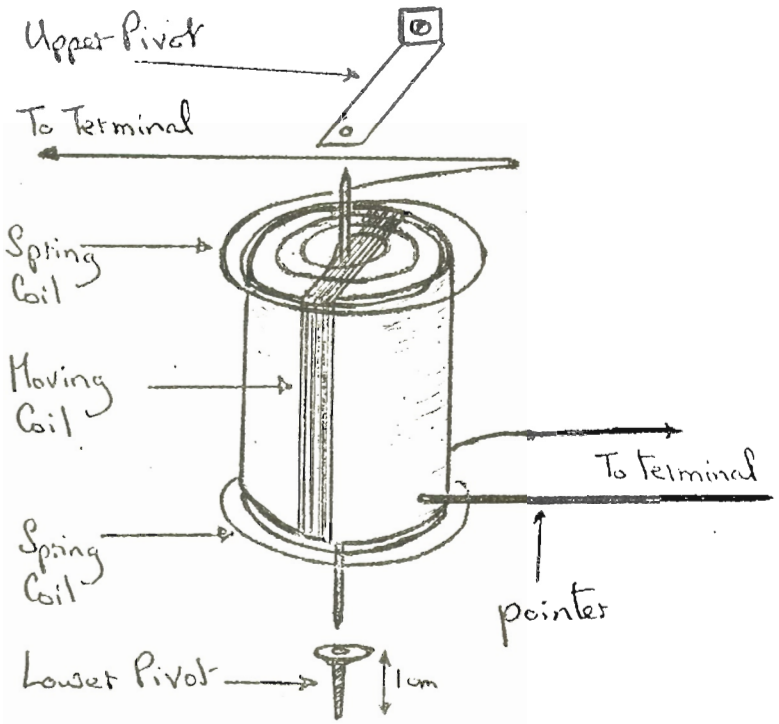
Cut a wooden core 3 cms long from a dowel (2 cms diameter). Make an inset (0.5 cms wide, 0.5 cms deep) around the core specifically to hold a coil. Drill a hole (0.8 cms diameter) along the axis to take the pivot and soft iron core.

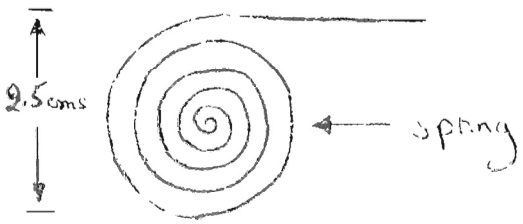


Bore a hole (0.5 cms deep, 0.1 cms diameter) horizontally into the bottom of the core at right angles to the plane of the inset (and coil).

Then take a length of galvanized wire or aluminum (7.5 cms long, 0.1 cms diameter) and fit it into the hole with epoxy resin to serve as a pointer.

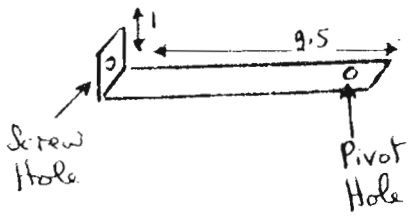
Obtain a needle (5 cms long, 0.1 cm diameter) to serve as a pivot and a pile of nails (a little over 2 cms long and as small in diameter as possible) Cut off the nail heads and make the length 2 cms. Pack the nails into the hole through the middle of the wooden core, placing the needle in the very center of the hole, so as to protrude an equal distance either end of the core. Bind the newly created core and pivot firmly in position with a liberal coating of epoxy resin over the nail ends and around the needle.



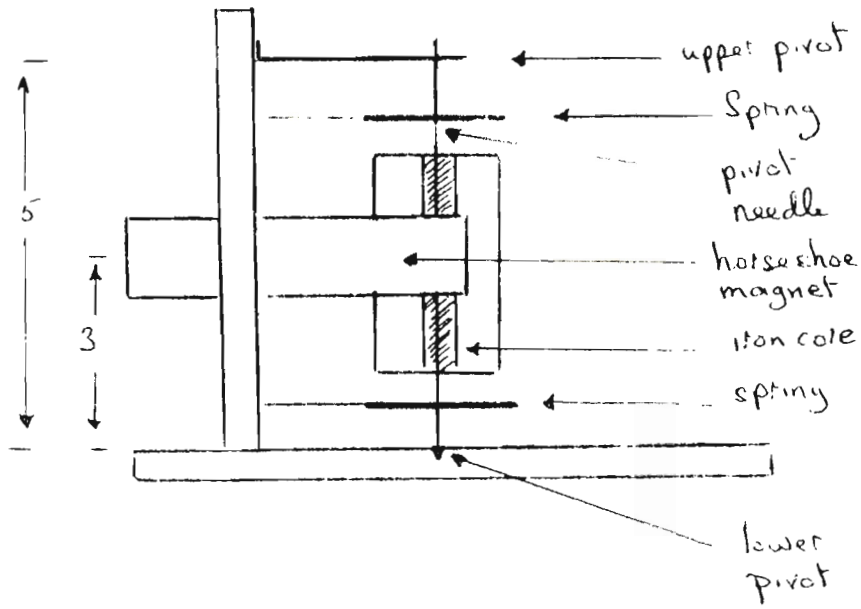


Wind 40 turns of magnet wire (No. 22) around the inset of the core, making sure that both ends are left free. Clean the ends of the wire with sandpaper and solder each end on to another length of very fine magnet wire (50 cms, No. 30) from which fine spring coils may be made around the top and bottom portions of the pivot according to the dimensions illustrated.

Insert a wood screw into the base at a point 2 cms from the front of the upright and 5.5 cms from either side. Drill an inset (0.2 cms deep) into the head of the screw so that it will serve as a lower pivot for the coil.



Bend a strip of brass (3.5 x 1.0 cm) to form an L shape. Drill a screw hole (diameter 0.3 cms) in the short end and a pivot hole (diameter 0.2 cms) at a distance of 0.5 cms from the other end. Slide the strip over the pivot needle, and screw the strip to the upright.

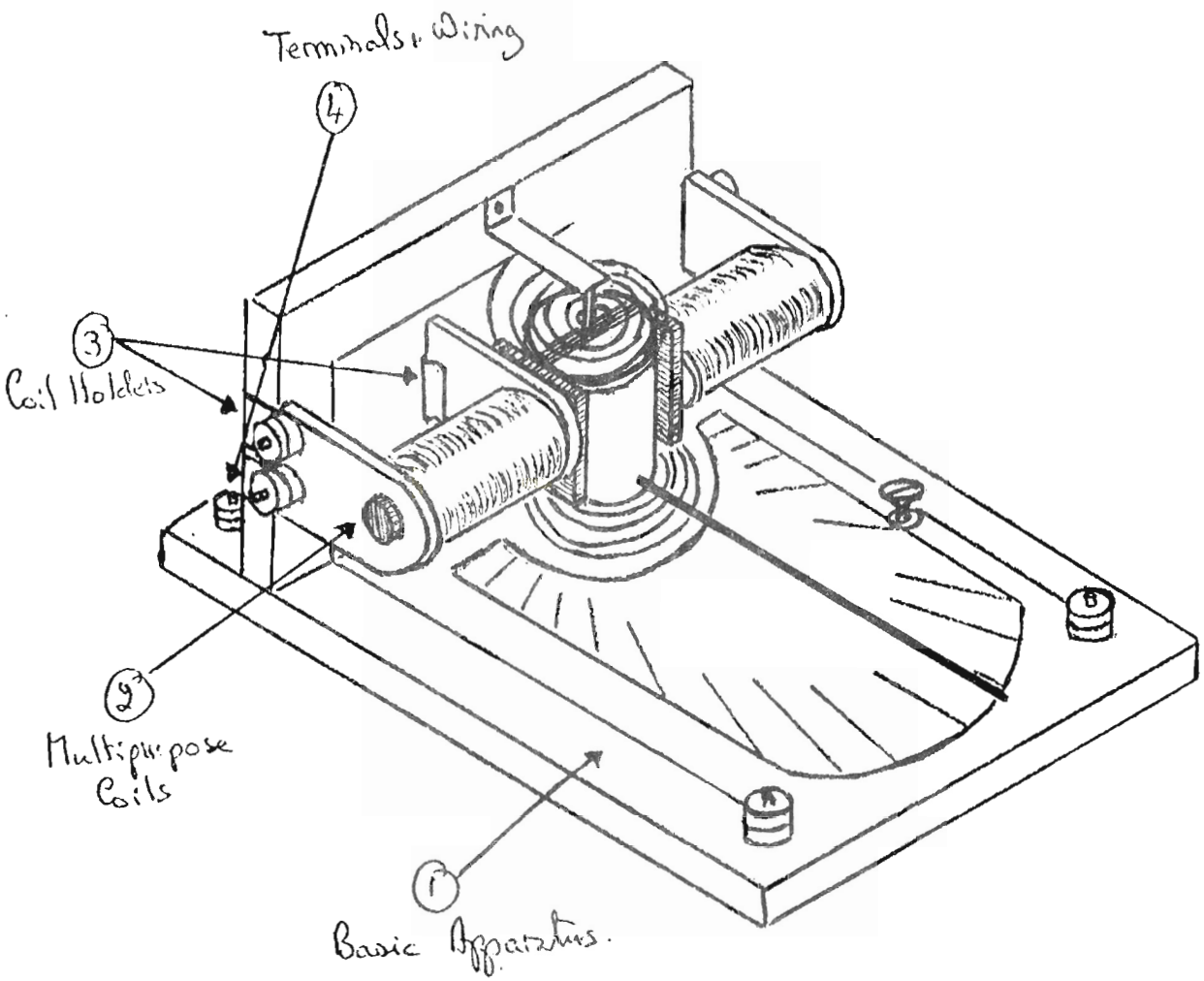


(4) Terminals	Fit two terminals (as described under 5.10/01) into the front of the base. Connect the wire from the two ends of the springs to the two terminals. One of the best ways of doing this is to drill small holes in the upright (opposite the springs) threading the wire through the holes. If two more holes are drilled through the upright (one on either side) the wire may be threaded back through the upright to the terminals.
(5) Scale	Cut a sheet of paper and paste it on the base. Taking the lower pivot as the center point mark off a scale to indicate every 10 degree movement of the pointer. The scale may later be recalibrated in amps or volts as desired.

Notes:

(i) Should there be any difficulty in obtaining a suitable, strong horseshoe magnet then multipurpose coils may be used as described in the next item.

5.10/11 Moving Coil Galvanometer with Multipurpose Coils



(1) Basic Apparatus

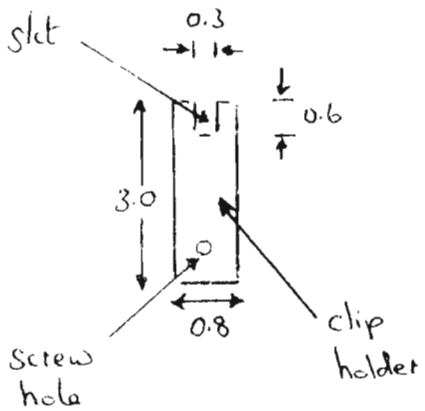
This is the basic magnetic field apparatus (described under 5.10/10) with the horseshoe magnet removed.

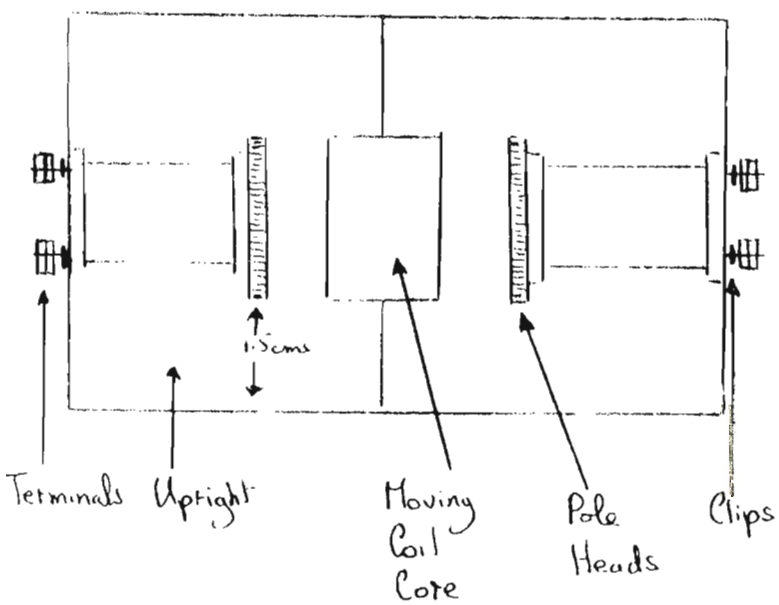
(2) Multipurpose Coils

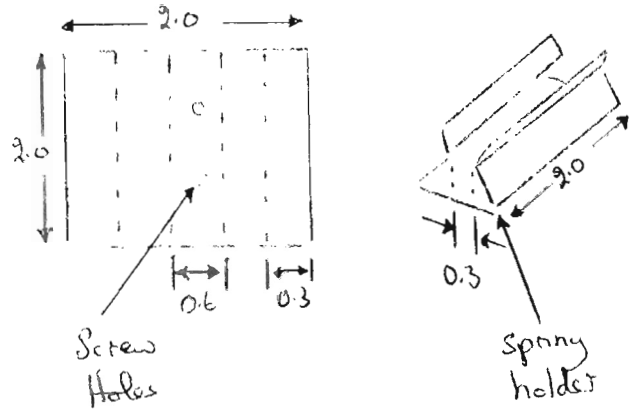
Two multipurpose coils (described under 5.10/09), complete with soft iron cores and poleheads, are required.

(3) Coil Holders

Cut 4 clip holders (3.0 x 0.8 x 0.05 cms) from a thin brass sheet, making a screwhole one end and a small slit at the other. Fit the 4 clips under the locking nuts of the 4 terminals of the multi-purpose coils. Then position each coil in turn on the upright so that the polehead is at exactly the same height above the base as the moving coil core. In this position screw the clips firmly on to the edge of the upright.



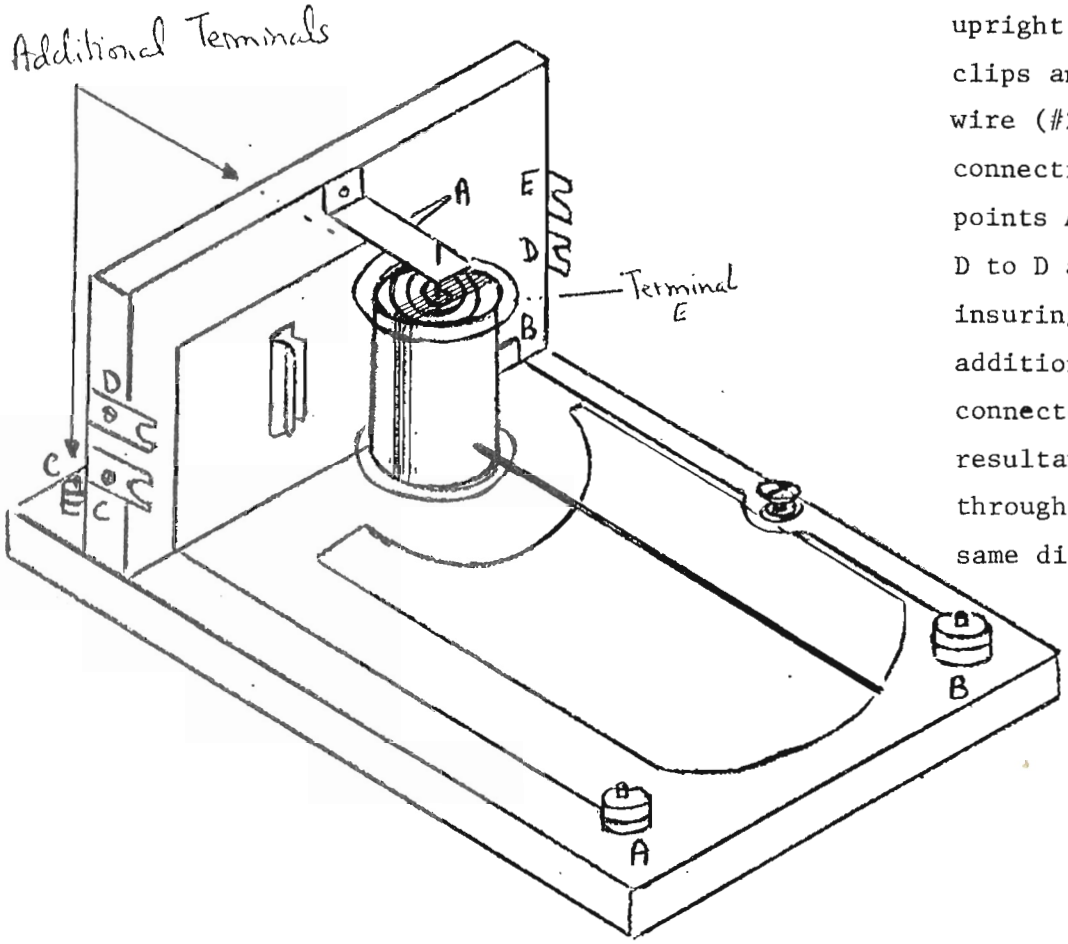




Make two spring holders from a brass sheet (2 x 2 x 0.02 cms) and slip these on the free ends of the multipurpose coils to determine where they should be attached to the upright. Having marked in the position screw the holders on to the upright.

(4) Terminals and Wiring

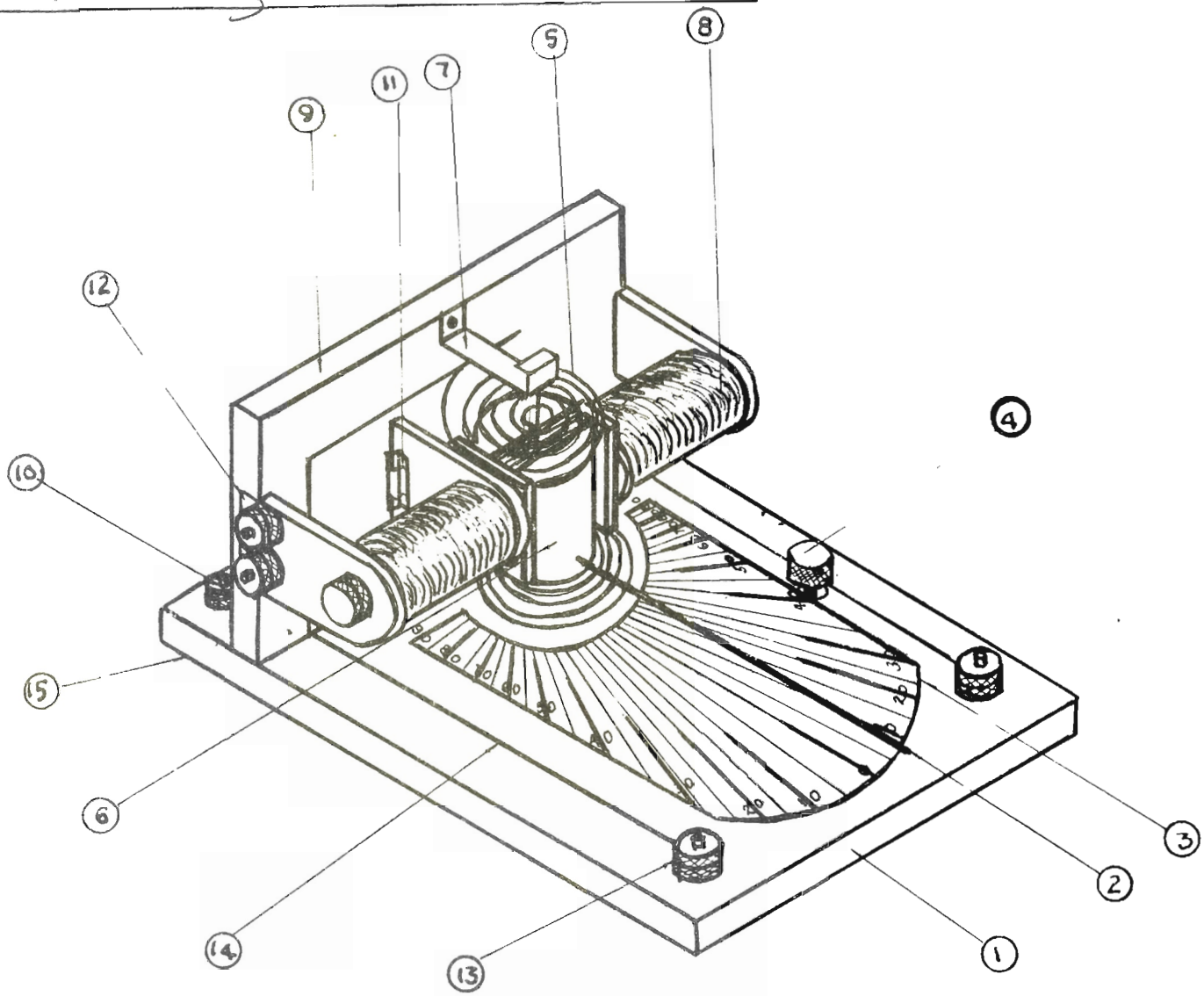
Fix two additional terminals (described under 5.10/01) to the base, just behind the upright, and then connect the clips and terminals with magne wire (#24) so that electrical connections exist between points A to A, B to B, C to C, D to D and E to E, thus insuring that once the additional terminals are connected to a circuit the resultant current will flow through the two coils in the same direction.



Note:

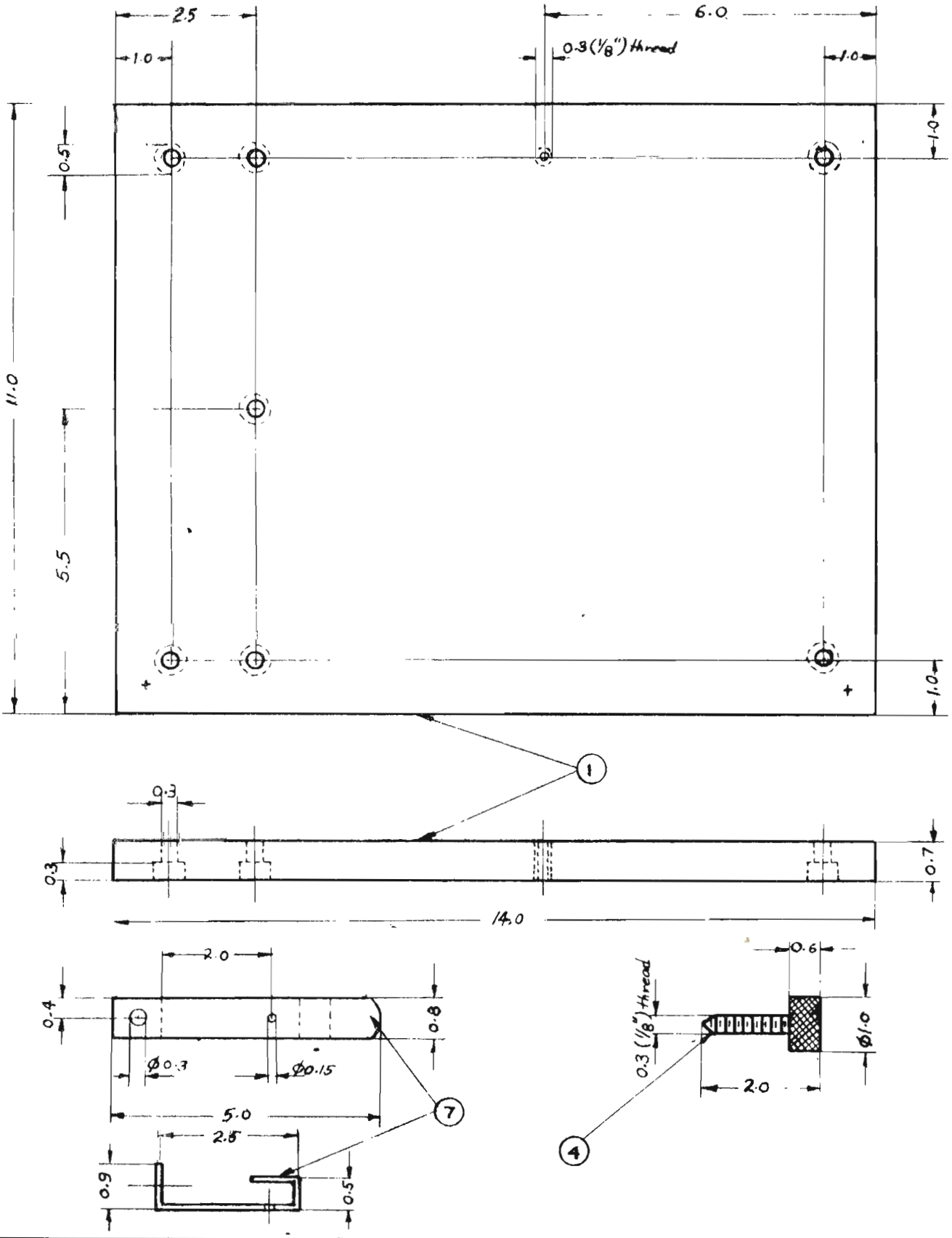
Those with reasonable technical ability will probably prefer to make this item from a technical drawing. The next item is therefore a blue-print of an almost identical galvanometer with only minor modifications (e.g., in the making of the core).

5.10/12 Moving Coil Galvanometer (Blue Print)

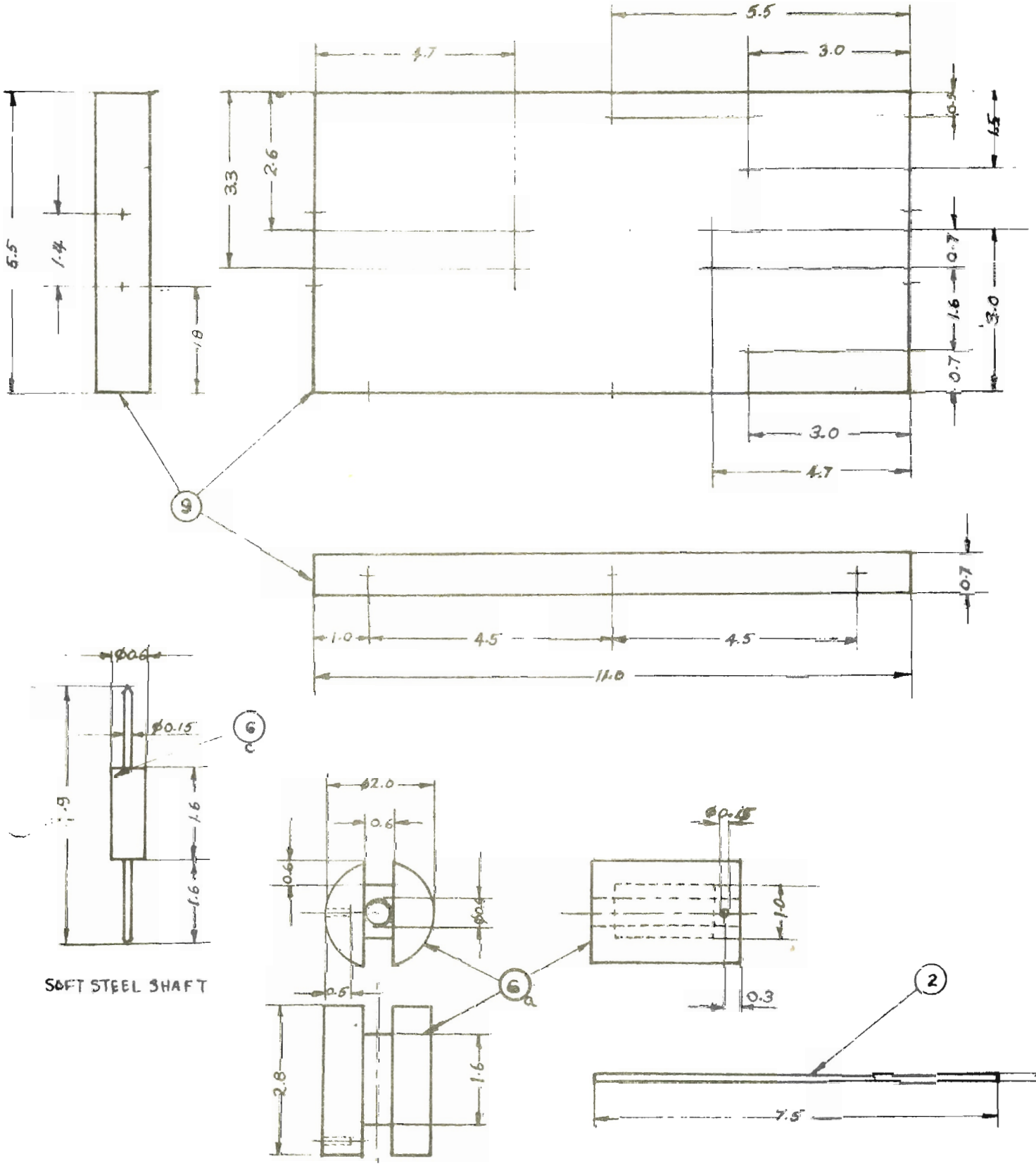


MOVING COIL GALVANOMETER

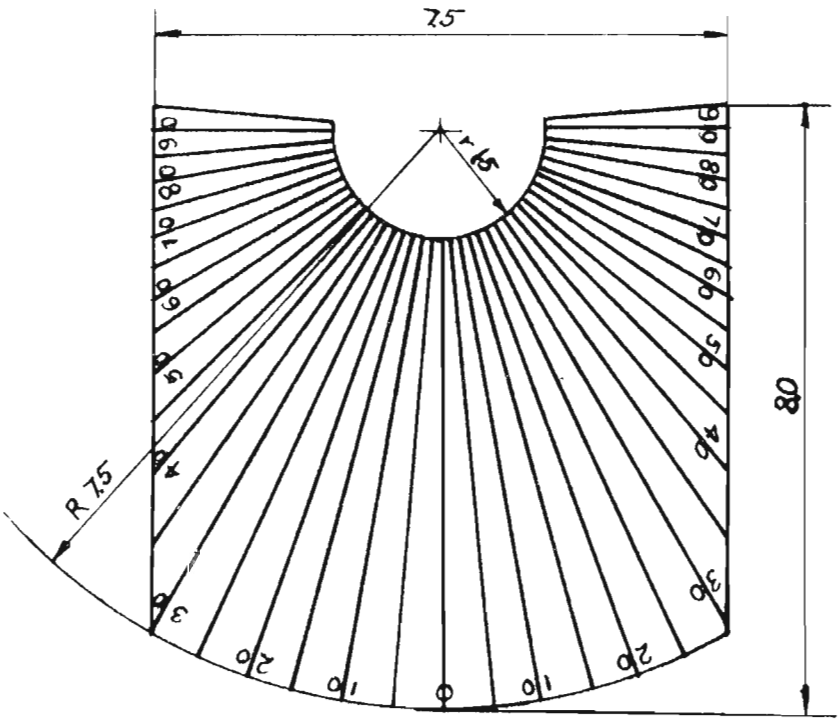
PART NO.	DESCRIPTION	DIMENSIONS	QUANTITY
1	BASE - PINE WOOD	1·0X11·0X14·0	1
2	POINTER - GALVANIZED WIRE	Ø0·15X 7·5	1
3	PAPER SCALE	7·5X7·5	1
4	LEVELLING SCREW - BRASS	Ø1·0X2·0	1
5	COIL SPRING - MAGNET WIRE Ø0·06 (GAUGE # 22)	Ø3·0	2
6	MOVING COIL	Ø2·0X2·8	1
7	UPPER PIVOT - BRASS SHEET	0·1X0·8X5·0	1
8	MULTIPURPOSE COIL		2
9	UPRIGHT - PINE WOOD	1·0X5·5X11·0	1
10	TERMINAL (FOR MULTIPURPOSE COIL)	Ø1·0X0·8	2
11	MULTIPURPOSE COIL HOLDER - BRASS	1·4X2·0	2
12	MULTIPURPOSE COIL CLIP - BRASS	0·8X0·06X1·7	6
13	TERMINAL (FOR MOVING COIL)	Ø1·0X0·8	2
14	ELECTRICAL CONNECTIONS		
15	LEGS - BRASS	Ø 0·4 X 1·0	2



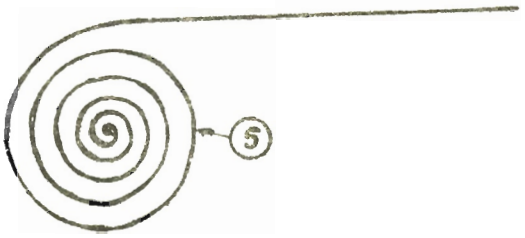
PART NO.	MOVING COIL GALVANOMETER PARTS 1-4-7	SCALE
1	BASE - PINE WOOD	1:1
4	LEVELLING SCREW - BRASS	1:1
7	UPPER PIVOT - STEEL SHEET	1:1
+	LOCATION OF LEGS	



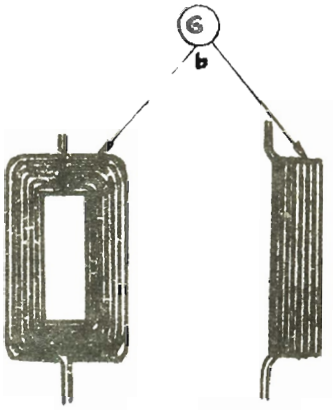
PART NO.	MOVING COIL GALVANOMETER PARTS 2-6	SCALE
2	POINTER - GALVANIZED WIRE	1:1
6 a-c	MOVING COIL - WOOD CORE (a) SHAFT-SOFT STEEL (c)	2:1
9	UPRIGHT - PINE WOOD	1:1
+	WOOD SCREW LOCATION	



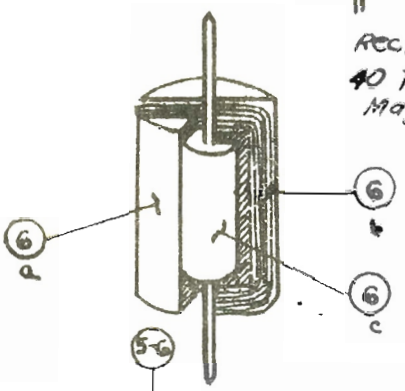
PART NO.	MOVING COIL GALVANOMETER PART 3	SCALE
3	PAPER SCALE	1:1

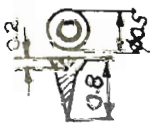


Coil Spring
ϕ0.04 (No. 30)
Magnet wire

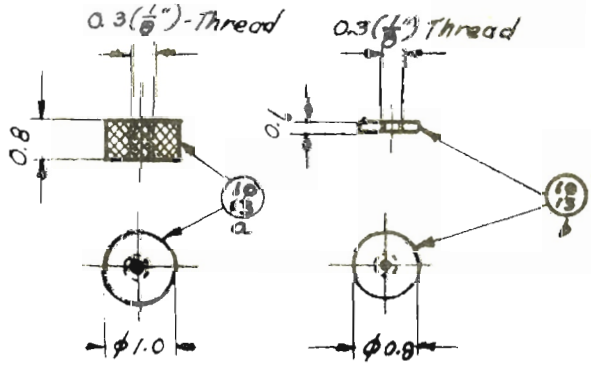


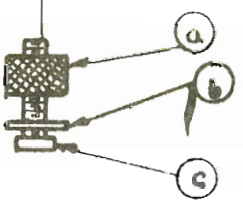
Rectangular Coil
40 Turns. ϕ0.06 (No. 22)
Magnet wire

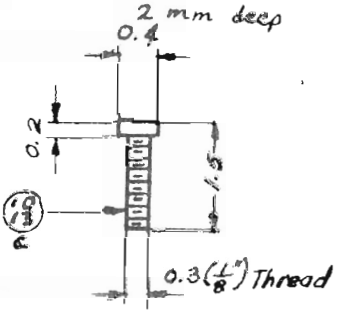


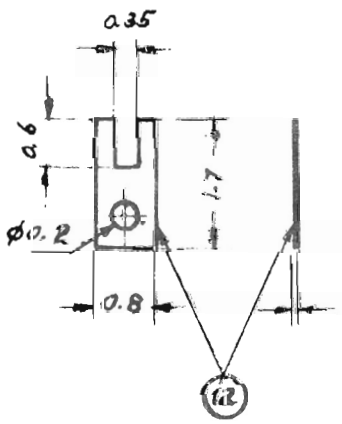


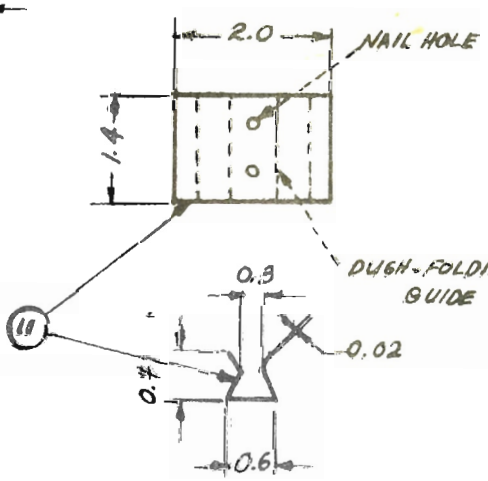
LOWER PIVOT
WOOD screw with 90° DEPRESSION ON HEAD
2 mm deep

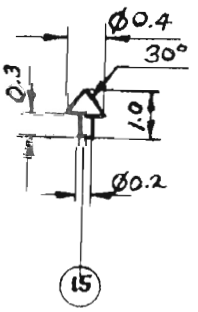




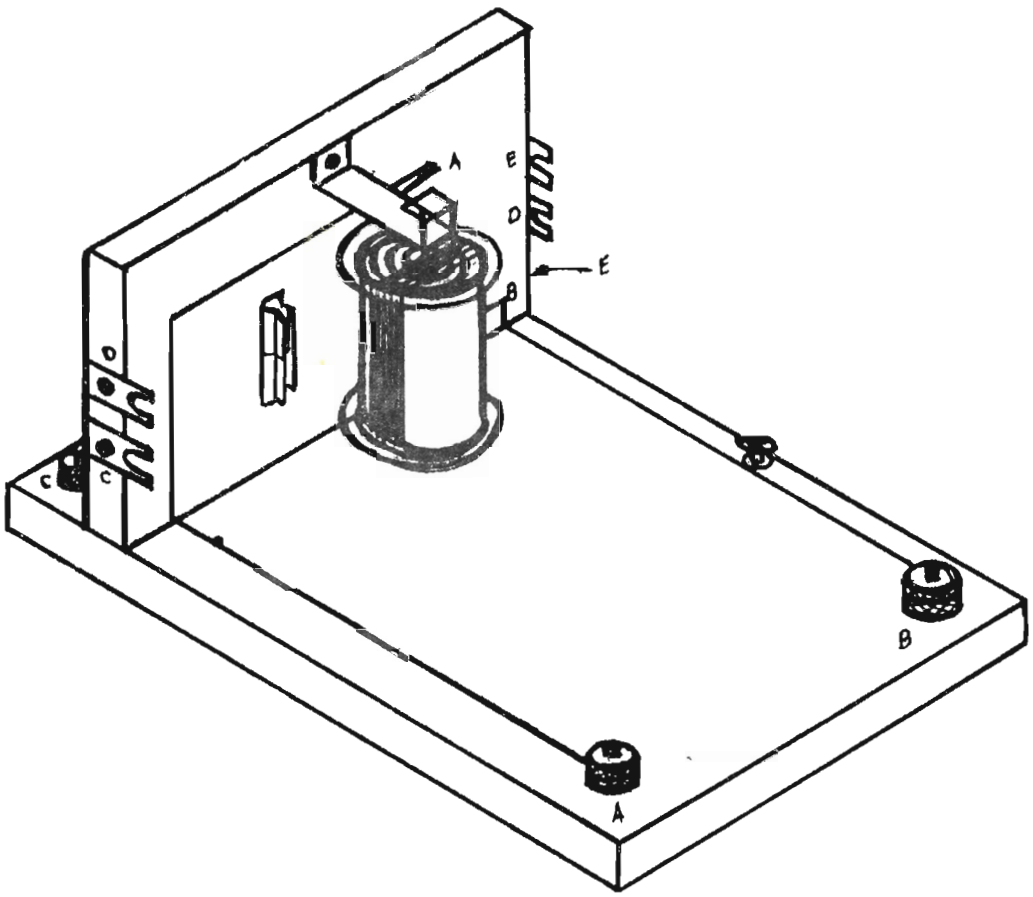






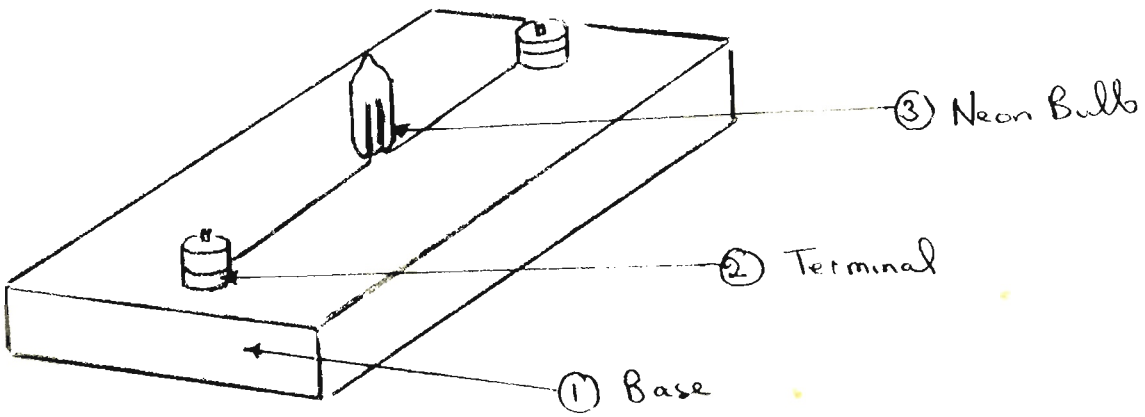


PART NO.	MOVING COIL GALVANOMETER PARTS 5-6b-11-12-10a,b,c-13a,b,c	SCALE
5	COIL SPRING - MAGNET WIRE ϕ0.04 (GUAGE # 30)	1:1
6b	RECTANGULAR COIL - 40 TURNS (GUAG # 22)	1:1
11	MULTIPURPOSE COIL HOLDER - BRASS	1:1
12	MULTIPURPOSE COIL CLIP - BRASS	1:1
10a,b,c	TERMINAL for MULTIPURPOSE COIL - brass, knurled nut, washer Nut, bolt.	1:1
13a,b,c	TERMINAL for MOVING COIL - brass knurled nut, washer Nut, bolt.	1:1
15	LEGS - BRASS	1:1



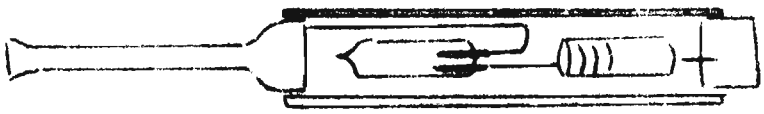
PART NO.	MOVING COIL GALVANOMETER PART 14	SCALE
14	ELECTRICAL CONNECTIONS BETWEEN IDENTICAL LETTERS A-A; B-B; C-C; D-D AND E-E	PERSPECTIVE

5.20/01 Neon Bulb Holer with Bulb

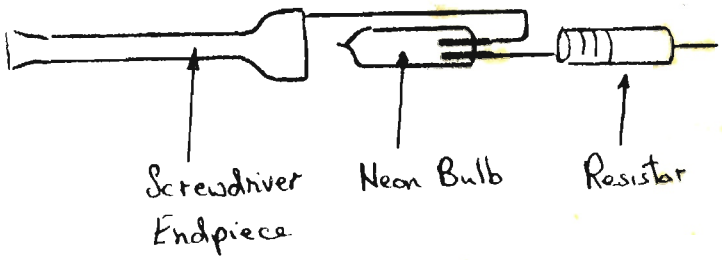


(1) Base	Cut the base from wood (7 x 3 x 1 cm).
(2) Terminals	Fit one terminal (described under 5.10/01) at either end of the base.
(3) Neon Bulb	Solder magnet wire (#24) to the neon bulb wires, and connect the newly extended wires to the terminals.

5.20/02 Electricity Tester



(1) Internal Components

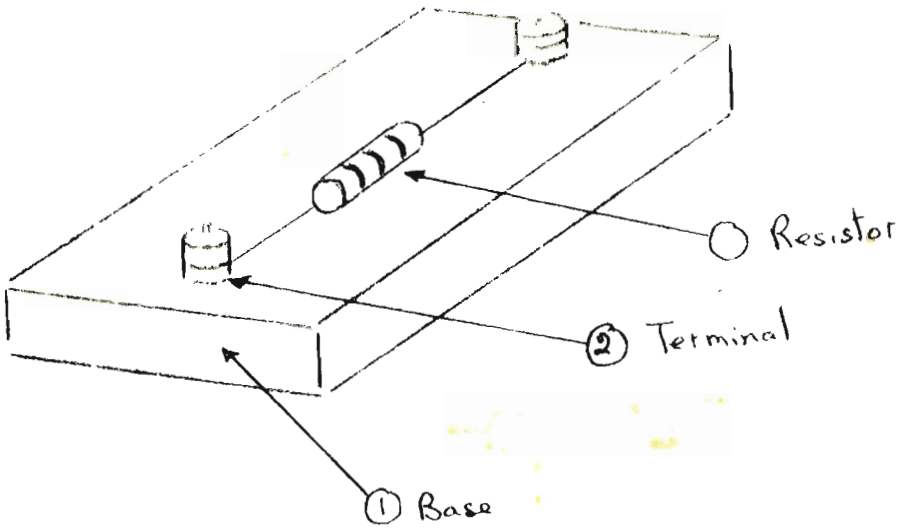


Solder one of the wires from the neon bulb on to a wire from a 200,000 ohm resistor (purchased from any radio shop). Solder the other wire from the neon bulb to the metallic end of a screwdriver.

(2) External Tube

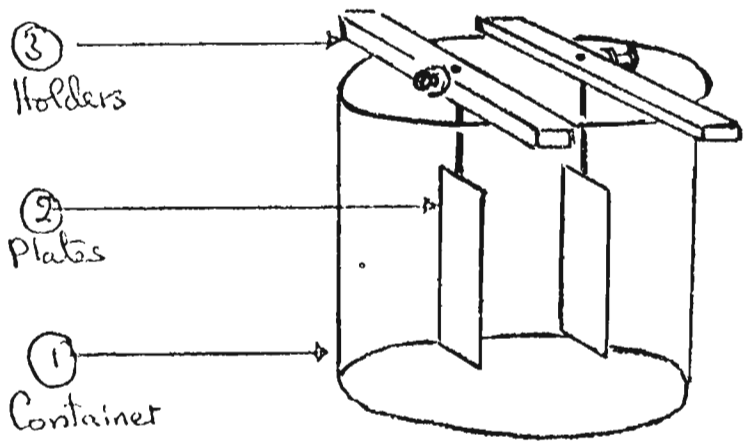
Select a plastic tube, which has the same diameter as that of the screwdriver end, and insert the newly joined components into the tube. Cut a piece of brass tubing (the same diameter as the tube and 0.4 cms long) and solder the spare wire from the resistor on to this. Insert the brass tube into the end of the plastic tube.

5.20/03 Resistor Holder with Resistor



(1)	Base	Cut the base (7 x 3 x 1 cms) from wood.
(2)	Terminals	Fit two terminals (described under 5.10/01) to the base, one at either end.
(3)	Resistor	Connect a 50 ohm resistor between the two terminals.

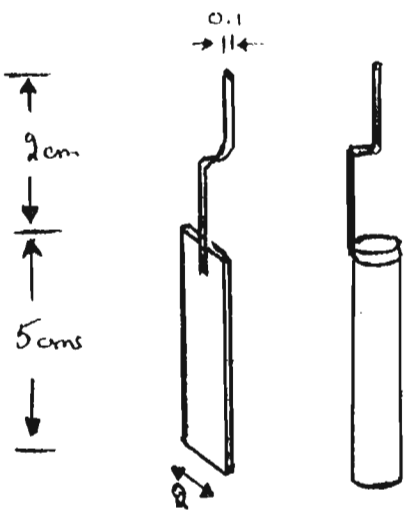
5.20/04 Chemical Cell



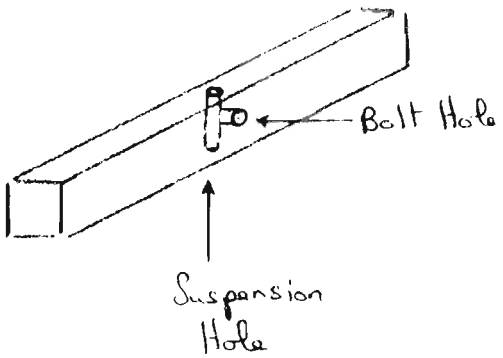
(1) Container

Obtain a plastic, or glass, container, approximately 8 cms diameter and 8 cms deep. (A wide variety of electrolytes may be used, including commonly available vinegar and household salt solutions).

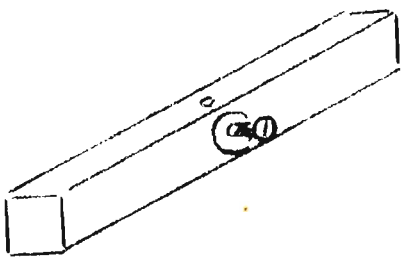
(2) Plates



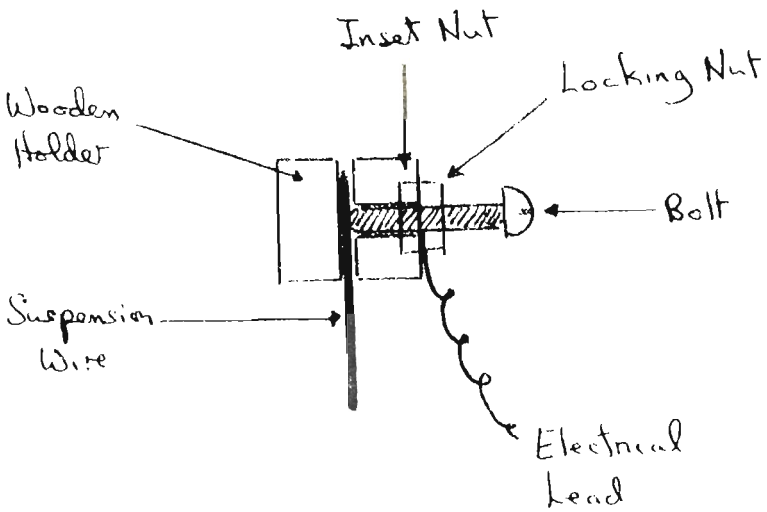
Cut alternative plates from zinc, copper and steel sheeting. Solder a brass suspension wire on to each. Also solder a similar suspension wire on to a carbon rod extracted from a dry cell.



Cut two wooden holders (each approximately 10 x 1 x 1 cm). In each drill a vertical suspension hole (0.2 cms diameter) and a horizontal bolt hole (0.3 cms diamter) to meet the vertical hole.



Obtain a fitting bolt (0.3 cms diameter) and nut, and inset the nut over the bolt hole with a sharp tap of the hammer. (A little epoxy resin will hold the nut permanently in position). Thread a second nut onto the bolt to serve as a locking nut, and then screw the bolt into the bolt hole. Insert a suspension wire in the vertical hole, and clamp it in position by tightening the bolt.



Electrical leads may be fastened under the locking nuts on the holders, and the cell connected into an electrical circuit.